B-GL-320-004/FT-001

National Défense
Defence nationale

FIELD ENGINEERING MANUAL

VOLUME 4

BASIC FIELD ENGINEERING

(ENGLISH)

WARNING
ALTHOUGH NOT CLASSIFIED, THIS PUBLICATION, OR ANY PART OF IT, MAY BE EXEMPTED FROM DISCLOSURE TO THE PUBLIC UNDER THE ACCESS TO INFORMATION ACT. ALL ELEMENTS OF INFORMATION CONTAINED HEREIN MUST BE CLOSELY SCRUTINIZED TO ASCERTAIN WHETHER OR NOT THE PUBLICATION, OR ANY PART OF IT, MAY BE RELEASED.

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Issued on Authority of the Chief of the Defence Staff
Publiée avec l'autorisation du Chef d'état-major de la Défense

Canada

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Director of Army Doctrine 8 (Protection) 1997-11-06

Canada

FOREWORD

1. B-GL-320-004/FT-001, Field Engineer Manual, Volume 4, Basic Field Engineering, is issued on the authority of the Chief of the Defence Staff.

2. This publication is effective upon receipt.

3. Suggestions for amendments shall be forwarded through normal channels to Chief of Land Staff, Attention: Director of Army Doctrine 8 (Protection).

TABLE OF CONTENTS

CHAPTER 3- FIELD ENGINEERING HAND TOOLS

CHAPTER 4- PORTABLE POWER TOOLS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

GENERAL

1. Engineers are responsible for a wide variety of tasks ranging from the construction of buildings, airfields, roads and bridges, to the destruction of facilities and resources. To carry out these tasks, the sapper will require numerous skills and techniques.

2. The majority of these tasks will have no set procedure, and all too often the tools and equipment will not be suitable. To succeed, sappers shall depend on flexibility, imagination and on the improvisation of common fundamental field engineering skills. As there will be very little time to consult a reference book during operations, this manual establishes the basic skills with which the individual sapper, through training and practice, shall be conversant.

AIM

3. The aim of this manual is to provide information on the fundamentals of field engineering skills, tasks, and on the equipment and resources used to complete them.

SCOPE

4. This manual is designed to be a comprehensive reference for the individual field engineer and assault pioneer, as well as their superiors. This manual covers the following:

a. organization of a field engineer task;

b. field engineering hand and power tools;

c. compressor, pneumatic and hydraulic tools;

d. generators and lighting systems;

e. engineer heavy equipment;

f. engineer resources;

g. field surveying;

h. basic bridging techniques;

j. basic concrete techniques; and

k. helicopter landing sites.

5. **Important:** This manual does not duplicate or nullify the requirement for equipment operator manuals.

REFERENCES

6. Annex A contains a list of references which may be used in conjunction with this manual, as well as pertinent standardization agreements which have been incorporated.

DIMENSIONS

7. Metric units and formulae are used throughout the manual, although in some cases imperial units are also given because of measurements used by manufacturers. Annex B contains conversion tables between metric and imperial units of measure.

ANNEX A

REFERENCES

1. The following publications are related to and may be used in conjunction with this manual:

a. B-GL-303-002/JX-007, Operational Staff Procedures, Volume 2 Staff Duties in the Field, Supplement 7, Engineer Vocabulary;

b. B-GL-319-001/FT-001, Volume 1, Engineers in Battle;

c. B-GL-320-002/PT-001, Engineer and Assault Pioneer Pocketbook (April 1989);

d. B-GL-320-003/PT-001, Engineer Planning and Organization of Work (August 1973);

e. B-GL-320-005/FP-001, Engineer Field Manual, Volume 5, Rigging;

f. B-GL-320-006/FP-001, Engineer Field Manual, Volume 6, Earthmoving Operations;

g. B-GL-320-007/FP-001, Engineer Field Manual, Volume 6, Field Defences and Obstacles;

h. B-CE-320-012/FP-002, Engineer Field Manual, Volume 12, Horizontal Construction, Part 2, Roads;

j. B-CE-320-012/FP-003, Engineer Field Manual, Volume 12, Horizontal Construction, Part 3, Airfields; and

k. B-GL-320-014/FP-001, Engineer Field Manual, Volume 14, Field Water Supply.

2. The following foreign and civilian publications have been used as a reference for this manual:

a. B-GL-050-ENG/FT-085, Volume II, Pamphlet No 1, Basic Field Engineering (1974);

b. B-GL-050-ENG/PT-175, Volume XVI, Earthmoving and Construction Plant (1979);

c. R-GG-F05-034/FP-000 (FM 5-34) US Engineering Field Data; and

d. C-83-050-001/MD-000 (FM 5-725) Rigging (October 1968).

3. The following list of Technical Orders are partially incorporated in this manual:

a. C-96-145-120/MP-000, Pionjar Service Manual (1976 with change 1 1977);

b. C-96-010-001/MN-001, Chain Saw Service Manual, 6th Edition;

c. C-96-011-00D/ME-000, Milling Aid Installation/Assembly Instruction (1979);

d. C-96-153-B00/MB-000, STIHL Power Auger Instruction/Parts Manual (October 1977);

e. C-30-355-000/MB-001, Operating Instructions for Auger Mounted on Truck, Field Engineer Section 2½ Ton M36 Cdn (with winch);

f. C-30-674-000/MB-001, Operating Manual M113A2 Bulldozer Carrier with Engineer/Pioneer Equipment;

g. C-30-897-000/MS-001, Operating Manual Trailer, Engineer Hydraulic Tool System (TEHTS);

h. C-33 series of Heavy Equipment Operator Manuals; and

i. Manufacturer's Operating and Maintenance Manuals for Stanley Hydraulic Tools.

4. The following NATO and ABCA Standardization Agreements have been wholly or partially incorporated into this manual:

a. STANAG 2010 Military Load Classification Markings; and

b. ATP-49(A) Helicopter Operations.

ANNEX B

IMPERIAL-METRIC CONVERSION TABLES

Unit	Conversion
Millimetre (mm)= 0.001 m	= 0.03937 inch (in)
Centimetre (cm) = 0.01 m	= 0.3937 in
Decimetre (dm) = 0.1 m	= 3.937 in
Metre (m) = 1.0 m	= 3.2808 foot (ft)
	= 1.0946 yard (yds)
Decametre (dam) = 10.0 m	= 32.8084 ft
	= 10.94 yds
Kilometre (km) = 1000.0 m	= 3,280.84 ft
	= 0.54 nautical mile
	= 0.6214 statute mile
in = 1/12 ft	= 25.4 mm
	= 2.54 cm
ft = 12 in	= 0.3048 m
yd = 3 ft	= 0.9144 m
statute mile = 1760 yds	= 1.609344 km
= 5280 ft	
nautical mile	= 1.8520 km

Fig 1B-1 Length/Linear Measure

Unit		Conversion
square (sq) mm (mm^2)	= 0.000001 m^2	= 0.00155 in^2
sq cm (cm^2)	= 0.001 m^2	= 0.155 in^2
sq m (m^2)	= 1.0 m^2	= 10.764 ft^2
		= 1.196 yd^2
hectare (ha)	= 10 000.0 m^2	= 2.471 acres
sq km (km^2)	= 1 000 000.0 m^2	= 247.1 acres
		= 0.3861 sq mile
	= 100.0 ha	
square (sq) in (in^2)	= 1/144 ft^2	= 6.4516 cm^2
sq ft (ft^2)	= 144 ft^2	= 0.0929 m^2
acre		= 0.0040 m^2
		= 0.4047 ha
		= 2.59 km^2
sq mile	= 640 acres	= 258.99 ha

Fig 1B-2 Area/Square Measure

Unit		Conversion
millilitre (ml)	= 0.001 l	= 0.0351 fluid oz
litre (l)	= 1.0 l	= 1.7598 pts
		= 0.8799 qt
kilolitre (kl)	= 1 000.0 l	= 219.9736 gals
cu cm (cc or cm^3)		= 0.0610 in^3
cu metre (m^3)		= 35.3147 ft^3
		= 1.3080 yd^3
cu kilometre (km^3)		= 0.0008 acre ft
		= 0.25 cu mile
fluid ounce (fl oz)	= 1/160 gal	= 0.0284 l
pint (pt)	= 1/8 gal	= 0.5682 l
quart (qt)	= 1/4 gal	= 1.1365 l
gallon (imperial) (gal)		= 4.5460 l
gallon (US) (gal (US))	= 1.201 gals	= 3.785 l
cu ft (ft^3)	= 6.23 gals	= 28.2161 l

Fig 1B-3 Volume Capacity

Unit	Conversion
Milligram (mg) = 0.001 g gram (g) = 1.0 g kilogram (kg) = 1 000.0 g tonne (t) = 1 000.0 kg	= 0.0154 grain = 15.43 grains = 0.035 27 oz = 2.204 623 lbs av = 0.022 cwt = 2,205 lbs = 1.1023 short tons
ounce (oz) pound (lb) = 16 oz hundredweight = 100 lbs long ton (cwt) = 2240 lbs short ton (US) = 2000 lbs	= 28.3495 g = 453.59 g = 0.453 kg = 45.359 kg = 1 016.04 kg = 1.0160 metric tonnes = 907.18 kg = 0.9072 metric tonnes

Fig 1B-4 Weight Measure

Unit	Conversion
newton (N) kilonewton (kN) kilogram force-newton (kgfN)	= 0.2248 pound force (lbf) = 0.1004 ton force (tonf) = 0.2248 1000 lbf (kip) = 0.1020 kgf
pound force (lbf) ton force (tonf) 1000 pound force (kip)	= 4.448 N = 9.964 kN = 4.448 kN

Fig 1B-5 Force

Unit	Conversion
kilogram per metre (kg/m)	= 0.672 lb/ft = 2.016 lb/yd
pound per foot (lb/ft) pound per yard (lb/yd)	= 1.488 kg/m = 0.4961 kg/m
kilogram per square metre (kg/m^2)	= 0.001422 lb/in^2 = 0.2048 lb/ft^2
pound per square inch (psi) (lb/in^2) pound per suare foot (lb/ft^2)	= 703.1 kg/m^2 = 4.882 kg/m^2
kilogram per cubic metre (kg/m^3)	= 0.00003606 lb/in^3 = 0.0624 lb/ft^3 = 1.686 lb/yd^3
pound per cubic inch (lb/in^3) pound per cubic foot (lb/ft^3) pound per cubic yard (lb/yd^3)	= 27.680 kg/m^3 = 16.02 kg/m^3 = 0.5933 kg/m^3

Fig 1B-6 Mass Per Unit Length, Area and Volume

Unit	Conversion
pound force per square inch (lbf/in^2) (psi)	= 0.006 895 MPa = 6.895 kPa = 0.0689 bar
1000 pound force per square inch (kip/in^2)	= 6.895 MPa
ton force per square inch ($tonf/in^2$)	= 15.44 MPa
kilopascal (kPa) = 0.0001 N/mm^2	= 0.145 lbf/in^2
megapascal (MPa) = 1000 kPa = 1 N/mm^2	= 145.0 lbf/in^2 = 0.064 76 $tonf/in^2$ = 0.145 kip/in^2
bar	= 14.5 psi

Fig 1B-7 Stress and Pressure

Prefix	Represents	The unit is multiplied by
tera	one trillion	1 000 000 000 000
giga	one billion	1 000 000 000
mega	one million	1 000 000
hectokilo	one hundred thousand	100 000
myria	ten thousand	10 000
kilo	one thousand	1000
hecto	one hundred	100
deca	ten	10
		1
deci	one tenth	0.1
centi	one hundredth	0.01
milli	one thousandth	0.001
decimilli	one ten thousandth	0.0001
centimilli	one hundred thousandth	0.000 01
micro	one millionth	0.000 001
nano	one billionth	0.000 000 001
pica	one trilliont	0.000 000 000 001

Fig 1B-8 Meaning of Metric Prefixes

From	To	Multiply by -
Lengths, Distances		
miles	kilometres	1.6093
nautical miles	feet	6,080.27
feet	metres	0.3048
inches	centimetres	2.54
kilometres	miles	0.6214
kilometres	feet	280.840
metres	feet	3.808
metres	inches	39.37
Area		
sq miles	sq kilometres	2.59
sq miles	acres	640.0
sq feet	sq metres	0.0929
acres	sq feet	43.560
sq kilometres	sq miles	0.3861
hectares	sq metres	10 000.0
hectares	acres	2.47
Volumes		
cu feet	imperial gals	6.23
cu feet	cu metres	0.0283
cu meters	cu feet	35.31
cu miles	acre feet	3 379 200.0
cu miles	cu metres	4 168 260 100.0
acre feet	cu metres	1233.50
acre feet	imperial gals	272 250.0
imperial gals	litres	4.5460
US gals	litres	3.7853
litres	imperial gals	0.2201
Weights		
pounds	kilograms	0.4536
kilograms	pounds	2.2046

Fig 1B-9 Conversion Table

CHAPTER 2

TASK ORGANIZATION

SECTION 1

PRINCIPLES

INTRODUCTION

1. This chapter is intended for engineer and pioneer officers and senior NCOs. It describes how a straightforward field engineering task shall be organized and executed. Guidance on planning more advanced tasks is given in B-GL-320-003/FT-001.

2. The smooth execution of a field engineering task depends upon sound planning, organization of the site, and the timely arrival of working parties, and engineer materials, stores and equipment.

3. The aim of organizing a field engineering task is to ensure efficient completion of the job in a timely manner. However, speed and efficiency may conflict, and this shall be reconciled at the planning stage. To attempt any field engineering task without making even a mental plan is to invite problems and inefficiency. Whether the work undertaken is a complex project carried out by engineers or a simple task executed by other arms, the governing principles are the same. The difference lies in the amount of essential detail required in the plan, and whether it shall be committed to paper or may be completed as a mental process.

PRINCIPLES

4. **Flexibility.** All plans, however carefully devised, are subject to unforeseen events and no plan is immune to the unexpected. The officers or NCOs in charge of a task shall be ready to use initiative to modify the plan to meet new circumstances, and they shall be determined to achieve the aim in spite of difficulties that arise.

5. **Control**. Control is facilitated by decentralization and good communications. The officer in charge, while maintaining overall control, shall assign responsibility for various parts of the work to subordinate commanders and then supervise the work as a whole, assisting individual subordinates as required.

6. **Foresight**. The uncertainties inherent in field work demand that commanders at all levels look as far ahead as possible. Delays which could arise from shortages of material, unexpected difficulties in design, and from other causes, can then be prevented. Regular progress reports from each part of the work enable the officer in charge to accurately forecast required stores and other resources, and to arrange for their provision. Progress reports are compiled and reviewed constantly in order to identify problem areas early, and to take remedial action.

7. **Morale**. To achieve maximum output, personnel must be fit, and also be intensely interested in the successful completion of the task. To this end, the officer in charge shall ensure that the physical needs of all members of the work party are cared for, by ensuring adequate food, rest periods, clothing, and safety precautions etc. The officer in charge will ensure that personnel are told of the progress expected of them and what is actually achieved, and will encourage them by personal leadership to the maximum extent possible.

SECTION 2

PLANNING

SEQUENCE OF PLANNING

1. Some minor tasks may not require a written plan, but all tasks shall be supervised and controlled. This section deals with and explains the steps in the planning and control of a field engineering task at troop and section level.

2. There are five steps to making a plan. They are:

   a. define the aim;

   b. carry out a reconnaissance and collect all relevant information;

   c. make an estimate of the situation (mental or written);

   d. select the best course; and then

   e. produce the detailed plan.

DEFINITION OF THE AIM

3. It will usually be necessary when delegating a task to a unit or sub-unit to extract the essential information and state it in a logical and correct form. If this is not done, much time and effort may be wasted. In all orders:

   a. the mission statement shall be clear, definite and concise;

   b. the standard and extent of work required shall be stated; and

   c. any imposed limitations or tactical restrictions (for example, security, availability of equipment, and timings) shall be stated.

RECONNAISSANCE

4. Reconnaissance and collection of relevant information will be planned and completed so that sufficient technical information is collected to produce a sound plan. Information which will have a tactical bearing on the plan shall also be collected. Use reconnaissance checklists and design proformas for specific tasks. Other relevant information and material may be collected from maps, aerial photographs, government documents and other engineer reports.

ESTIMATE OF THE SITUATION

5. An estimate of the situation is a detailed consideration of all aspects of a given task. This includes the aim, pertinent factors, an evaluation of various options and a logical conclusion as to the most efficient means of completing the task. Sound planning is based on the estimate of the situation. Depending on the job, all or some of the factors in the following paragraphs will have to be considered.

6. **Tactical Factors:**

   a. the need for concealment and protection;

   b. the availability of other arms protection parties;

   c. communications requirements;

   d. the requirement for safe routes to and from the site; and

   e. any imposed limitations, for example, the requirement to work by night.

7. **Technical Factors:**

   a. design constraints;

   b. manpower requirements, including the need for specialist tradespersons, and working and carrying parties;

   c. accessibility of the site;

d. availability of vehicles, engineer heavy equipment, stores and equipment; and

e. any imposed limitations, for example, the road that is to be kept open during culvert construction.

8. **Administrative Factors:**

a. ration and water requirements;

b. sanitation requirements;

c. the need for rest, relief and other physical comfort measures, such as waterproof clothing;

d. safety and protective equipment;

e. medical support and casualty evacuation; and

f. the availability of reinforcements and replacements.

DETAILED PLAN

9. The detailed plan is derived from reconnaissance information and from the estimate of the situation which has identified the best course of action. The detailed plan incorporates the technical design for the execution of the job, as well as tactical and administrative matters.

10. A detailed plan for a major field engineering task includes:

a. reconnaissance information and sketches;

b. detailed technical designs;

c. resource requirements, which are normally consolidated on a scheduling table, including:

(1) time and labour estimates,

(2) material, stores and equipment lists, and

(3) heavy equipment and vehicle lists, and

d. a works program for hasty and field tasks, or a network analysis for more complex tasks. (Network analysis is beyond the scope of this manual. See B-GL-320-003/FT-001).

11. Even if the task does not require a written plan, each of the above elements to the plan shall be considered. In a written plan, they can best be considered in a tabular form. An example works program is contained at Annex A and a scheduling table is at Annex B.

12. **Activity List.** Completing an activity list is the first step in deciding the best sequence of individual tasks for the job. The list is compiled by breaking down the job into a series of tasks for which the required labour and time can be estimated from experience or from planning data. The list of tasks need not be in the correct sequence but it must be comprehensive. It must include all component tasks of the particular job and any subsidiary or related tasks which may have a direct bearing on it. The list will include tasks which have no labour requirement but take time, such as curing of concrete.

TIME AND LABOUR ESTIMATE

13. It is important that the time and labour estimates are accurate because they form the basis of the works program. Labour estimates are based on the minimum size of party required for the efficient and economical execution of the work, differentiating, if need be, between engineer and other labour. Where possible, the labour requirement is expressed in terms of sub-units rather than the number of personnel required. The time requirement varies on the tactical situation and on whether the work is done in daylight, moonlight or darkness. If this detail is not known when the task list is being compiled, alternative figures are noted or an adjustment factor recorded in the remarks column.

WORKS PROGRAM

14. A Works Program (see Annex A) shows, in matrix form, how a job is to be completed. It details what each sub-unit or section does at any specific time during the job and when equipment and materials are required, or the earliest time at which they will be available. The allocation of

labour, materials and equipment to tasks is generally made according to it. Adjustment may be required to ensure that all resources are fully used.

15. The first point to consider when compiling a works program is the time available. The time available will determine if a normal working day is to be used or whether shift or nightwork is required. Tactical timings, such as stand-to and meal timings, are also considered and included. Finally, time is allocated for the movement and servicing of vehicles and equipment.

16. A certain amount of ingenuity is required when programming tasks involving the use of explosives in order to avoid wasted time when personnel are withdrawn from the danger area.

17. Many unforeseen events can occur with field engineering tasks, so a reserve is normally included. The reserve may be of labour, materials or time. Whenever possible, a time reserve shall be kept. This allows greater flexibility in the execution of work and has less effect on other units than a reserve of labour or materials. A time reserve shall be incorporated in the plan only after compilation of the works program.

MATERIAL, STORES, AND EQUIPMENT

18. The activity list cannot be completed until the required material, stores, and equipment have been confirmed, and that no extra work in prefabrication or adaptation is necessary. It is therefore convenient to compile the material, stores and equipment lists concurrently with the activity list. Another reason for preparing the material, stores and equipment lists at this stage is that quite frequently material, which is the product of one task, may have to be incorporated in another and this may influence task sequence.

19. At this stage, only the type and quantity of material, stores and equipment required for each task is entered into the proforma. The total material, stores and equipment requirement can only be established after the works program has been prepared. Items which are not part of, or which are in excess of unit holdings, shall be noted for subsequent procurement action. In the material and stores list, recoverable items should be shown separately from those that will be incorporated or expended on the job. A reserve of material, stores and equipment is required to cater for loss and breakage, during the course of the work, but this reserve shall not be excessive.

ENGINEER HEAVY EQUIPMENT AND TRANSPORT

20. The heavy equipment and transport list shall show:

a. the number of vehicles and heavy equipment by type and configuration;

b. when and where each piece of equipment is required and for how long;

c. any limiting route or site factors; and

d. any administrative factors regarding drivers and operators.

21. When calculating heavy equipment and transport requirements, the following points are to be remembered:

a. make economical use of transport and heavy equipment, this means full loads and quick turn arounds;

b. vehicles may be unable to carry the assigned load if the items to be moved are bulky or too heavy;

c. allow time for driver and operator rest, refuelling and maintenance;

d. avoid double handling; and

e. where possible, carry mixed loads so that the loss of one vehicle will not zmean the total loss of a particular commodity.

SECTION 3

TASK SITE CONTROL

CONTROL

1. The officer in charge of a task shall have firm control at all times. Control can be delegated to subordinates, making them responsible for the execution of their respective parts of the task, but the officer assigned with the task remains responsible for the entire work. The officer in charge will pay special attention to any part of the work, where difficulties and delays have arisen, but shall never lose sight of the work as a whole.

2. There will always be at least two people concerned with the technical control of a field engineering job. They are the engineer commander who ordered the work and the engineer commander in charge of the work.

   a. at squadron level, the Squadron Commander orders the work and the Troop Commanders supervise the completion of the work; and

   b. at troop level, the Troop Commander normally orders the work and the Section Commanders supervise their sections completing the work. The Troop Warrant Officer may be placed in charge of the work or may coordinate the work of the sections.

3. Attached working parties will usually be in support only, and it will be necessary to define the responsibilities of the working party commander.

RESPONSIBILITIES

4. The engineer commander who orders the work is responsible for:

   a. issuing orders for the job which may include:

      (1) already approved plans and designs, or instructions for their productionand subsequent approval,

(2) the assignment of tasks and resources to subordinate units,

(3) work start and completion times, and other applicable timings,

(4) progress and completion reporting requirements,

(5) the conditions under which work may be suspended, and

(6) tactical requirements;

b. arranging administrative matters beyond the control of the commander in charge of the work, for example:

(1) stores and equipment,

(2) additional or replacement labour, vehicles and heavy equipment, and

(3) rations and other supplies.

c. inspecting work in progress and providing technical advice and direction;

d. arranging for protection parties if required; and

e. warning all local formation or unit commanders of the arrival in their area of the troops doing the job.

5. The Engineer Commander in charge of the work is responsible for:

a. planning and executing the job, including:

(1) the design if required,

(2) the detailed works program, and

(3) the allocation of labour, material and equipment to tasks;

b. issuing detailed orders to subordinates and briefing them, where possible, on site;

c. ensuring the technical correctness of the task by:

(1) setting-out the work,

(2) supervising the task and regularly inspecting progress,

(3) conducting quality control checks, and

(4) checking the completed work.

d. ensuring adequate traffic control including posting required traffic signs;

e. allocating any attached working parties to tasks and ensuring they are provided with tools and equipment;

f. supervising the unloading and organization of stores;

g. submitting progress and completion reports;

h. ensuring job safety and site protection; and

i. liaising with local all-arms commanders.

6. The commander of an attached work party is responsible for:

a. becoming thoroughly familiar and for making the work party thoroughly familiar with their part of the plan, routes and working areas;

b. ensuring the composition of the party contains adequate supervisors, workers and equipment;

c. ensuring punctual arrival at the rendezvous;

d. organizing local defences for use by the party in an emergency;

e. allocating tasks to subordinates;

f. maintaining discipline, and administration of the work party;

g. maintaining the tools, equipment and materials issued to his party;

h. transferring the task to a relieving party if ordered; and

i. completing the task to the satisfaction of the officer in charge of the work.

BRIEFING

7. Good control will be achieved only if all involved have a sound understanding of the job. It is the responsibility of the commander in charge of the work, and of the commanders of any working parties, to fully brief their subordinates. Subordinates must know enough about the job to be able to take charge if their superiors become casualties.

INSPECTION OF WORK

8. Both the commander in charge of the work and the commander who ordered it shall make frequent inspections. Inspections may also be made by senior engineer officers. Aspects of the job that will usually be of most interest are:

a. progress;

b. quality control;

c. safety;

d. servicing of vehicles and equipment; and

e. economy in the expenditure of resources.

9. Inspections can maintain and boost morale. Effort must be recognized and criticism, if given, shall be soundly based. The following notes are offered for the guidance of inspecting officers.

a. **Progress**. Progress is the best measure of effort, however, there is often more than one way of completing a job. Be wary of advising a change unless it is clear that the method being used will not produce the required result.

b. **Accuracy**. Some aspects of a job require particularly accurate work. Determine what these aspects are, and have the measurements checked.

c. **Safety**. The fact that work is being carried out under battle conditions is no reason for any unnecessary relaxation of normal safety precautions. Safety shall remain a primary consideration at all times. Be aware of the normal safety precautions and ensure any deviations are fully justified.

d. **Servicing**. It is essential that all equipment being used is regularly and thoroughly serviced. Question the operators on their duties in this regard and spot check a few machines. Check that the officer in charge of the work has provided sufficient time and facilities for adequate servicing.

e. **Economy**. Economize in the use of resources. The need for a reserve of material, stores, equipment and vehicles for work carried out under operational conditions is recognized. However, this is no justification for extravagant or careless use. Check that reserves are not excessive and that wasteful techniques are not used.

SUPERVISION

10. On-site supervision is fundamental to the efficient control of a field engineer task. Supervisors at all levels shall concentrate on their assigned tasks. They must not be distracted by minor detail or, unless absolutely necessary, become physically involved. For a large job, or when continuous on-site supervision is not possible, a system of routine progress reports is a good aid. These enable progress to be monitored and the works program to be adjusted as necessary.

ALLOCATION OF WORK

11. Allocation of work is organised on a task work or time work basis.

12. Task work is work allotted as a complete task or job to a unit or sub-unit. The allotted unit has the responsibility for the task or job from start to finish. This method of allocating work satisfies many of the principles governing the employment of engineers and it provides an incentive for hard work. However, for this latter reason it may lead to short cuts being taken. It is therefore extremely important that the finished product is inspected properly.

13. In the time work system, units or sub-units each work for a set period until the job is finished. This system provides less incentive than task work and is generally not the preferred system. Continuous time work is called shift work.

14. Shift work is used when it is essential that a job be completed in the minimum possible time and hence round the clock work is necessary. The number of shifts employed will depend on the nature of the work, and physically demanding tasks will require more shifts. Shift work requires a large number of personnel and requires good control to maintain overall efficiency. To ensure continuity of effort, the relief of shifts and supervisors shall be staggered.

15. The works program shall provide time for parties to change over. At night, extra care is required to avoid confusion. Relieving parties may bring their own tools on to the job or take over the tools of the party they are relieving. The former method is preferred as it ensures that the relieving party starts with tools that are in good condition.

CARRYING PARTIES

16. When employing carrying parties, brief them on what is required, when and where to report, what loads to carry and which routes to take. The stores to be carried are to be ready before their arrival, and any necessary aids for carrying, such as gloves, pads or carrying handles, shall be prepared. For loads requiring several persons, an NCO is nominated to control the party.

17. When several types of stores are required for the work in hand, for example, when constructing wire obstacles, it is sound practice to make up mixed loads to ensure that work is not held up by the loss of some loads.

SITE PREPARATION

18. Preparation of the site will be necessary before stores can be unloaded and the main body of troops start work. It may include:

a. checking for mines and mine clearance, and marking safe areas;

b. establishing site control and communications;

c. establishing camouflage arrangements, which to be effective, must be carried out from the start;

d. surveying to establish datum points and levels;

e. improving existing approaches, or constructing new approaches. Speed in the execution of a task is greatly influenced by the state of the approaches, and work on them in the preliminary stages may avoid many difficulties later;

f. preparing store areas, transport and engineer heavy equipment parks, and sites for static engineer heavy equipment;

g. signposting the approaches and within the site;

h. marking the work, and any existing underground services such as electrical cables, water mains or sewers. Time spent in careful marking is never wasted;

j. clearing undergrowth and removing topsoil;

k. provision of water; and

m. deploying alarm posts.

19. Initially only those engaged in preliminary work will be on the site. The arrival of the main party and stores is to coincide with the completion of marking and necessary camouflage measures.

20. If the site is restricted, or the approaches limited, it may be convenient to park transport and engineer heavy equipment in an assembly

area or marshalling harbour, calling them forward piecemeal on a timed program or as the situation requires.

UNLOADING AND HANDLING STORES

21. Care shall be taken that loaded stores vehicles reach the site in proper sequence. For continuity of the work, stores shall be unloaded and stacked before they are required for use. They shall be stacked clear of work in progress but readily accessible for incorporation in it.

22. The nature of the ground or the need for silent work may restrict the employment of machines. However, within any such limits, the maximum possible use is to be made of all forms of mechanical aids, in both handling stores and doing work (one machine may do the work of fifty workers).

23. Responsibility for unloading and laying out stores may be delegated by the officer in charge of the work to a subordinate specifically charged with this task.

NIGHT WORK

24. Generally, work done at night is less efficiently performed and more exhausting than similar work done in daylight, but the precise effect of darkness is governed by the extent to which those concerned are familiar with their tasks and by their standard of training in night work. Appropriate allowances will have to be made in both fixing the hours of work and estimating the rate at which it will progress. When the tactical situation permits, artificial lighting may be used to counter the effects of darkness.

25. Control is always more difficult when personnel cannot easily be seen; contact can quickly be lost with even the best disciplined troops. Work by night calls for special efforts by those in charge to ensure that all workers are fully employed all the time.

PROTECTION

26. **Security.** During operations, no matter what other provision has been made for protection, a working party shall organize its own local defences for use in an emergency. The first task on arrival at a site, will be the selection of alarm posts close to the work. The commander of the party will allocate alarm positions and make sure that each soldier knows the

alarm signal, where to go, the defensive task, arcs of fire, and the position of other troops. There should be at least one rehearsal soon after starting work.

27. **Protection.** Trenches may have to be dug to provide protection and they shall be sited to defend the work site. Besides preventing casualties, the proximity of trenches improves the confidence of personnel working close to the enemy.

28. **Weapons.** Working soldiers will carry their personal weapons and equipment unless the tactical situation does not warrant it. In all cases, weapons and equipment must be within easy reach.

29. **Concealment.** The individual soldier is responsible for concealing himself and the transport driver for concealing his vehicle. Similarly, the officer in charge of a field engineering task is responsible for concealing that work. Much field engineering work is done at night under conditions where general supervision is difficult and where disregard of basic concealment rules, such as track discipline, can pass unchecked. The concealment plan shall be coordinated well in advance and consideration given to laying tapes at last light to define the permissible tracks before troops and vehicles arrive on the site.

ANNEX A
EXAMPLE OF A WORKS PROGRAM

(SECURITY CLASSIFICATION)

WORKS PROGRAM

TIME **RESOURCES**	**H-1**	**H**	**H+1**	**H+2**	**H+3**	**H+4**	**H+5**	**H+6** **H+7**
Recce party	Load stores and move to site	Site layout	Supervise task			M E A L B R E A K	Supervise task	Return to harbour
1 Section	Load stores and move to site	Unload home bank stores	Site preparation and cut spars for gyn	Construct home bank gyn			Load stores and site clean up	Return to harbour and turn in stores
2 Section	Load stores and move to site	Unload and move stores to far bank	Site preparation and cut spars for far bank sheer	Construct far bank sheer			Install cable and traveller	Return to harbour and turn in stores
D6 dozer with Low bed	Load stores and move to site	Off load dozer	Home bank site Preparation				Load dozer	Return to harbour and off load.

(SECURITY CLASSIFICATION)

Fig 2A-1 Example of a Works Program

ANNEX B
EXAMPLE OF A SCHEDULING TABLE

(SECURITY CLASSIFICATION)
SCHEDULING TABLE

SER	ACTIVITY			RESOURCES REQUIRED								REPORT/DELIVER TO				REMARKS
	TASK	DUR	PRI	LABOUR	QTY	STORES	QTY	EQUIPMENT	QTY	HY EQPT VEHICLES	QTY	DATE	FROM	TO	PLACE	
1	Load stores and move to site	1 Hr		Recce party	1	Recce	1 set			Recce veh	1		H-1	H		
				Section	2	Section	2			Section veh	2		H-1	H		
				Operator	2					D6 dozer lowbed	1 1		H-1	H		
				Storeman	1	15m x 24 mm lashings	16	Assault boat (with gas, oil, life jackets & motor)	1	Stores veh	1		H-1	H		
						14 mm SWR	50 m									
						14 mm bulldog clamps	12									
						OHP sets	4									
						8" x 24 mm SWR sling	2									
						Mousing cord	1roll									
						Snatch block 14 mm	4									
						Double block 24 mm	4									

SER	ACTIVITY			RESOURCES REQUIRED								REPORT/DELIVER TO				REMARKS
	TASK	DUR	PRI	LABOUR	QTY	STORES	QTY	EQUIPMENT	QTY	HY EQPT VEHICLES	QTY	DATE	FROM	TO	PLACE	
						24 mm cordage	100m									
2	Site layout	1 Hr		Recce party	1	Recce	1 set			Recce veh	1		H	H+1		
3	Unload home bank s	1 Hr		Section	1	Section gyn	1 1 set			Section veh	1		H	H+1/2		

(SECURITY CLASSIFICATION)

Fig 2B-1 Example of a Scheduling Table (Sheet 1 of 2)

(SECURITY CLASSIFICATION)

SCHEDULING TABLE

SER	ACTIVITY			RESOURCES REQUIRED								REPORT/DELIVER TO				REMARKS
	TASK	**DUR**	**PRI**	**LABOUR**	**QTY**	**STORES**	**QTY**	**EQUIPMENT**	**QTY**	**HY EQPT VEHICLES**	**QTY**	**DATE**	**FROM**	**TO**	**PLACE**	
4	Unload and move stores to far bank	1 Hr		Section Storeman	1 1	Section Sheer	1 1set	Assault boat (with gas, oil, life jackets & motor)	1	Section veh Stores veh	1 1		H	H+1		
5	Offload D6 dozer	1 Hr		Operator	2					D6 dozer lowbed	1 1		H	H+1		
6	Supervise task	4 Hrs		Recce Party	1								H+1	H+6		
7	Cut spars for home side gyn and site preparation	1½ Hrs		Section	1	Section	1 t						H+½	H+2		
8	Cut spars for far bank sheer and site preparation	1 Hr		Section	1	Section	1 t						H+1	H+2		
9	Construct home bank gyn	2 Hrs		Section	1	Gyn	1 set						H+2	H+4		
10	Construct far bank	2 Hrs		Section	1	Shear	1 set						H+2	H+4		
11	Meal break	1 Hr		All									H+4	H+5		Delivered

SER	ACTIVITY			RESOURCES REQUIRED								REPORT/DELIVER TO				REMARKS
	TASK	DUR	PRI	LABOUR	QTY	STORES	QTY	EQUIPMENT	QTY	HY EQPT VEHICLES	QTY	DATE	FROM	TO	PLACE	
12	Load stores and site clean up	1 Hr		Section Storeman Operators	1 1 2					Sect veh Stores veh D6 dozer lowbed	2 1 1 1		H+5	H+6		
13	Install cable	1 Hr		Section	1	Cable, anchorage and traveller stores	1 set	Assault boat (with gas, oil, life jackets & motor)	1	Section veh Recce veh Stores veh	2 1 1		H+5	H+6		
14	Return to harbour	1 Hr		All						All			H+6	H+7		

(SECURITY CLASSIFICATION)

Fig 2B-1 Example of a Scheduling Table (Sheet 2 of 2)

CHAPTER 3

FIELD ENGINEERING HAND TOOLS

SECTION 1

GENERAL

INTRODUCTION

1. Field engineering tasks call for a wide variety of hand tools. These can generally be classified as digging, cutting or miscellaneous tools.

2. This chapter illustrates these tools and describes their uses. Section 2 covers digging tools; Section 3 deals with cutting tools and Section 4 contains notes on miscellaneous tools. Section 5 describes the care and sharpening of field engineering tools.

GENERAL SAFETY PRECAUTIONS

3. The majority of field engineer tools have sharp edges and some are used with a swinging motion. All of them can be dangerous if handled incorrectly.

4. Inspect hand tools before using them. Repair or replace loose, splintered, or defective handles; damaged blades or parts; rough edges or burrs; and any other defects that lower the strength or make it unsafe for use.

5. Store hand tools in a suitable storage space. Serious injuries can result from a cluttered work site or tool room.

6. Be sure hand tools are clean and dry. Dirty, oily, or greasy. tools are unsafe.

7. Pointed or edged tools are dangerous, do not carry in pockets or leave lying around the worksite.

8. Carry sharp-edged or pointed tools so they face down or away from the body.

9. Do not use tools made of metal and power tools in locations where sources of ignition may cause a fire or explosion.

10. Dress properly. Wear safety goggles or other approved face and eye protectors when breaking rocks, grinding, striking metal with metal, drilling, driving wedges, chipping, or performing similar operations that might result in flying particles. Tuck in loose clothing.

11. Carry, do not toss, drop or throw tools from one location to another.

12. Turn off the electrical current before attempting any work on electrical circuits.

13. Steady with clamps or vises any loose material to be cut, sheared, chiselled, or filed. This prevents the material and the tool from slipping.

14. Do not swing a chopping or chipping tool until sure that no one in the area will be endangered by the backswing.

SECTION 2

DIGGING TOOLS

SERVICE SHOVELS

1. There are three types of service shovels. Only two of them are classified as digging tools. The third, the square mouth shovel, is classified as a miscellaneous tool. The two digging shovels are the shovels general service long and short. They are used to dig, carry and throw soil. Note that the shovel is the same, it is only the handles that are different to facilitate throwing of earth from various depths.

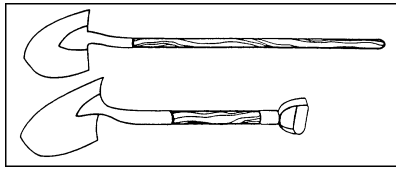

Fig 3-2-1 Long and Short Handle Shovels

2. The art in shovelling lies not so much in getting a full load on the shovel as depositing that load in the required place. With practice, personnel should be able to throw a shovelful of soil a distance of about 3 m with reasonable accuracy. The correct method of throwing soil is shown in Fig 3-2-2.

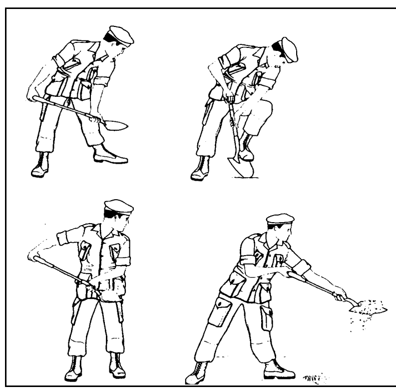

Fig 3-2-2 Correct Method of Holding and Loading a Shovel and Throwing Soil

ENTRENCHING TOOL

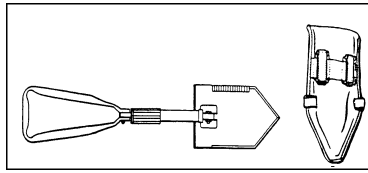

Fig 3-2-3 Entrenching Tool

3. The entrenching tool is the basic digging tool used by troops in the combat zone. It is designed to be carried by an individual in a pouch as part of the fighting order. It is used for digging-in under fire by soldiers kneeling or lying down. The earth is loosened with the chisel point and scraped aside with the shovel. Keep the shovel edge in good condition and the tightening screw well lubricated.

PICK AND MATTOCK

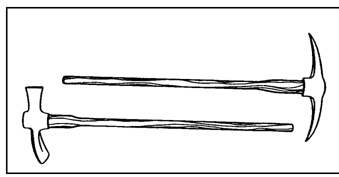

Fig 3-2-4 Pick (top) and Mattock

4. The pick is designed for breaking up hard soil or rock so that it can be moved with a shovel. It is also useful for spitlocking, that is, marking out the outline of an excavation on the ground. The pick can be taken apart for storage.

5. The mattock is a combined digging and cutting tool. It is a useful Tool when working in an excavation for loosening clay and chopping through roots. It is swung in the same manner as the pick, and can be taken apart for storage.

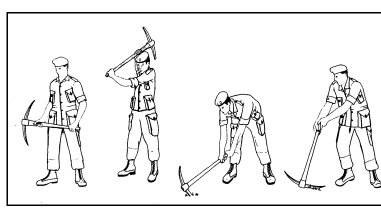

Fig 3-2-5 Correct Method of Holding and Using the Pick

6. The head of the pick, or the mattock, is not wedged on the handle (helve). When using the pick, or mattock, care shall be taken to ensure that the head is jammed tightly on the helve and does not loosen during use. Like the shovel, the pick can be used either left or right handed. This is advantageous when working in confined spaces such as weapon pits. The correct method of holding and using a pick is as shown. The strike of the pick is made so that the earth between the pick and the face will break away

when the handle is raised. The spoil can then be removed with the shovel. To aid shovelling, the base of the excavation is kept smooth and flat.

EARTH AUGER

7. The earth auger is designed for sinking holes in the ground, usually to a maximum depth of 2 m. The most common sizes are 150 mm to 225 mm in diameter. It is operated by screwing the tool into the ground in a clockwise direction causing the cutting edges to bite into the soil. The spoil collects in the bowl of the tool and when the bowl is full the tool is removed and the spoil emptied. The auger will not operate efficiently in stony or sandy ground. The handle can be removed for storage.

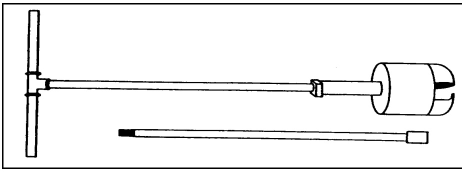

Fig 3-2-6 Earth Auger and Extension

HAND ICE AUGER

8. The hand ice auger is designed to cut holes 100 mm to 150 mm in diameter through ice to a depth of 4 m when using the extension. It is operated by screwing the tool into the ice in a clockwise direction causing the cutting edges to bite into the ice. The auger has to be withdrawn from the hole regularly to remove ice chips from the hole. Additional extensions may be used but drilling holes deeper than 4 m is very difficult.

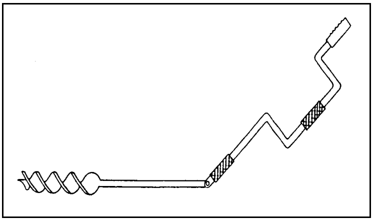

Fig 3-2-7 Hand Ice Auger

SECTION 3

CUTTING TOOLS

AXES

1. There are two types of axes in service use: the felling axe and the hand axe. The felling axe is the larger of the two and is used for felling trees and cutting large timber. The length of the handle is about 750 mm. This is a useful measure when cutting timber to length. The hand axe is used for cutting saplings and branches, trimming timber or sharpening.

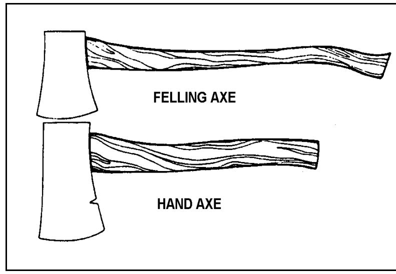

Fig 3-3-1 Axes

2. The axe may be used either left or right handed. The action of swinging an axe is like that of swinging the pick. Smaller timber (less than 75 mm in diameter) can be cut straight through in one or two strokes. For ease, the cut at an angle to the grain rather than at right angles to it.

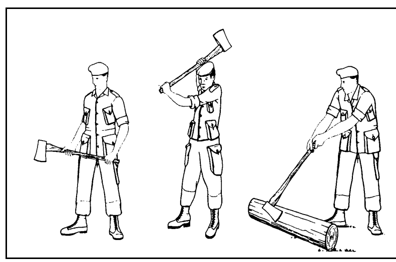
Fig 3-3-2 Cutting Timber With an Axe

3. For timber greater than 250 mm in diameter, cutting a notch from one side only becomes awkward and wastes timber. If the timber can be rolled over easily and safely it is better to make two cuts from opposite sides to meet in the centre. This enables the width of the notch to be reduced, sometimes by as much as half. If, however, the timber cannot be rolled over, it may be possible to produce two opposing cuts by chopping from a position standing on top of the timber.

MACHETE

4. The machete is used for cutting saplings or clearing vines, brushwood and similar materials. The machete comes in a case which can be attached to a soldier's fighting order.

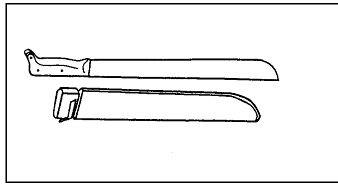

Fig 3-3-3 Machete and Case

CHISELS

5. Chisels are used to cut wood, metal, rock, concrete and masonry. They come in various widths and different types of points and are often used in conjunction with a hammer, mallet or sledgehammer.

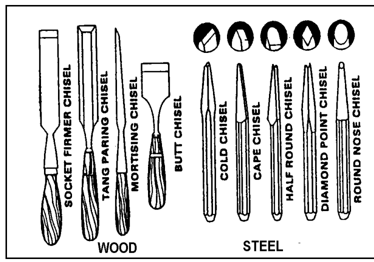

Fig 3-3-4 Chisels

SAWS

6. **Crosscut Saw.** The crosscut saw is a double-handled, two-man saw used for heavy work, such as felling trees, cutting large trees into logs, or sawing heavy bridge timbers. This saw is made of high-grade steel, with an arched blade 1.5 m to 1.8 m in length, approximately 20 cm wide at the middle and tapering to about 8 cm at each end. The cutting teeth are usually grouped four teeth to a section with raker teeth between each section to chisel out and remove the chips. It has largely been replaced by the power chainsaw.

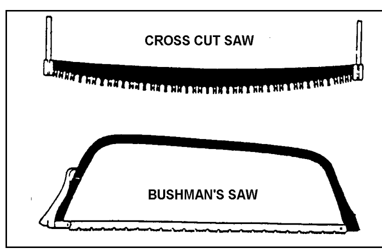

Fig 3-3-5 Saws

7. **Bushman's Saw.** This versatile tool can be used by one man in the field. It is particularly effective for felling trees up to 150 mm in diameter and can be used for basic carpentry. It has a replaceable blade.

ADZE

8. The adze is designed for shaping and squaring round timber. Considerable skill is required to obtain good results.

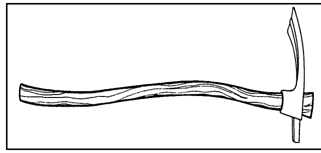
Fig 3-3-6 Adze

9. When working with an adze, the user stands astride the work, and the adze is swung with a chopping motion towards the body. The blade should bite into the timber slightly forward of the toes. A firm stance with the feet spread is important to avoid an accident should the blade miss its mark.

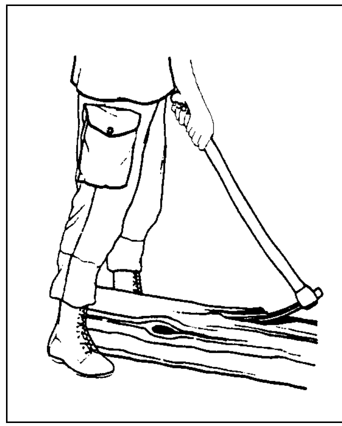
Fig 3-3-7 Correct Method of Using an Adze

SHEARS

10. Shears are used for cutting sheet metal and steel of various thicknesses and shapes. Hand shears are made with straight or curved cutting blades. Straight blades are used for cutting straight lines and also to cut curves in easily accessible locations. Curved blades, such as the hawk bill and the curved blade shears are made especially for cutting short straight lines or curves and for cutting out small intricate designs where the handle operating hand has to be kept away from the metal stock.

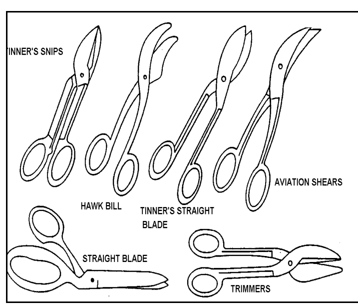

Fig 3-3-8 Shears

BOLT AND CABLE CUTTERS

11. Bolt cutters are available in various sizes with different cutting edges designed for specific applications and are replaceable. The centre cut cutters are used for all general purpose cutting with the cutting edges in the centre with equal bevels. The clipper cut cutters are almost entirely on one side which permits very close cutting of projecting ends. The shear cut cutters are used to cut steel cable, strip or flat bar stock. The cutting edges of the jaws pass each other in the manner of scissors. The side nut splitter cutters are used to split nuts off of bolts "head on" to the bolt's axis without damaging the bolt (when adjusted properly).

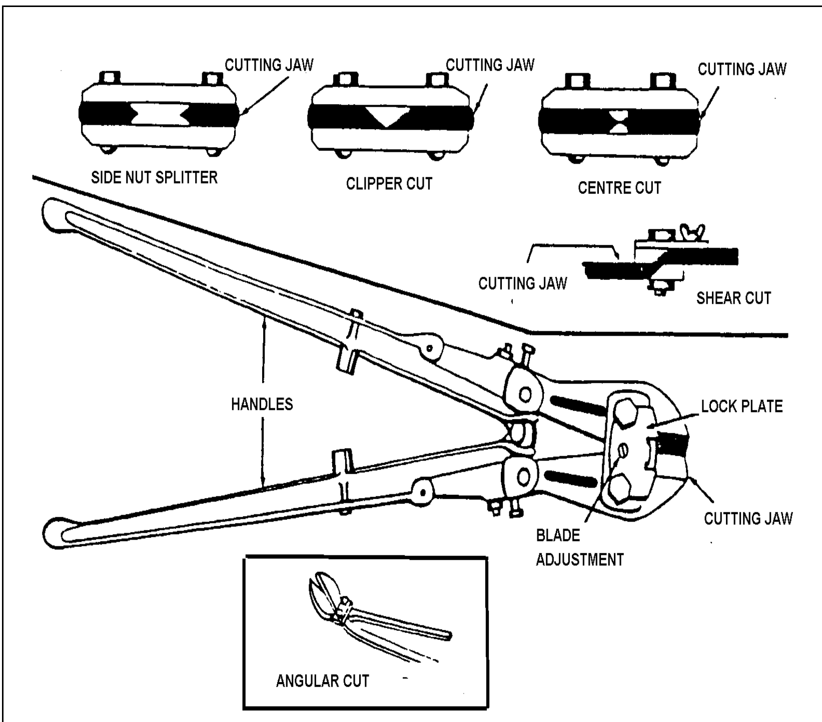

Fig 3-3-9 Bolt and Cable Cutters

WIRE CUTTERS AND PLIERS

12. Wire cutters are used to cut thin gauge metal and wire up to 5 mm in diameter. They come complete with a case which can be fitted to the soldier's fighting order.

13. Pliers are made in many different styles and sizes and are used to perform many operations. They are not a substitute for a wrench. Pliers are used for holding and gripping small articles where it may be inconvenient or impossible to use hands. Most commonly used pliers by the field engineer are the side cutters (lineman's) and the slip joint pliers. Other types of pliers that may be used for a specific purpose are locking jaw pliers (channel lock) and needle nose pliers.

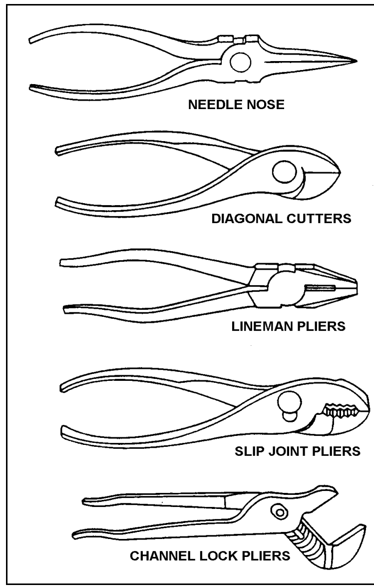

Fig 3-3-10 Wire Cutters and Pliers

14. Needle nose pliers were designed to assist electricians in making loops or eyes in wire in order to make proper connections, and can also be used to reach into hard to get at locations. The side and diagonal cutters are used to strip and cut wire. Slip joint pliers are designed to open in two positions. The channel lock pliers can open to seven different positions. They were originally designed for tightening or removing water pump packing nuts.

SECTION 4

MISCELLANEOUS TOOLS

SLEDGEHAMMERS AND MAULS

1. Sledge hammers come in two sizes: 1.8 kg and 3.6 kg. The 1.8 kg has a double face, but the 3.6 kg can be double-faced or straight-peen. The double-faced sledge hammer has two flat faces and is used for driving metal pickets and wedges. The straight-peen sledge hammer has one flat face, and a chiselled edge designed for breaking rock.

2. The maul is a large, or small, hammer with a wooden head designed for driving wooden stakes or pickets. It is not used to hit metal objects.

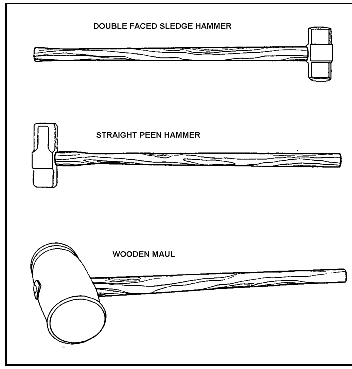

Fig 3-4-1 Sledgehammers and Mauls

HAMMERS

3. Claw and ball peen hammers are used to hammer nails and metal objects. The claw hammer is fitted with a claw to extract nails, while the ball peen hammer is fitted with a ball-shaped head at one end to shape metal.

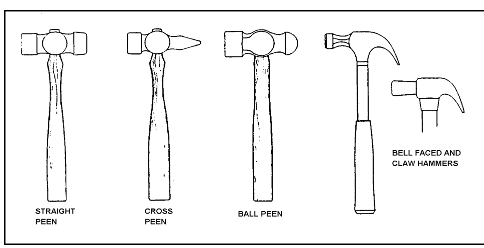

Fig 3-4-2 Claw and Ball Peen Hammers.

WOOD AUGER

4. The wood auger is used for boring holes in timber. The sizes available

are 12, 25, 37, 50 and 60 mm diameters. The wood handle can be detached, or come as a brace with bits.

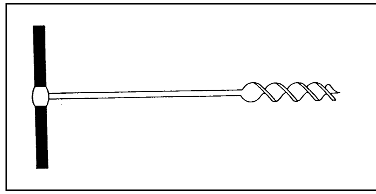

Fig 3-4-3 Wood Auger

WEDGES

5. Wedges can be made of wood or steel and when used to split timber, are usually driven with a wooden mallet or a sledge hammer. They are also used when sawing timber to hold the saw-cut open and prevent binding.

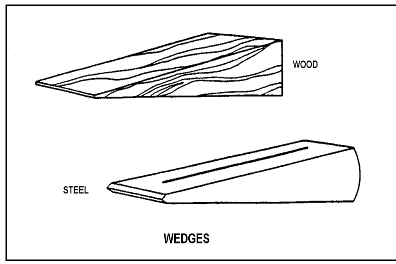

Fig 3-4-4 Wedges

PEAVEY AND TIMBER CARRIERS

6. Peavey and timber carriers are used to manoeuvre or carry logs or large square timber. The peavey carrier is used by one man and the timber carrier by two men.

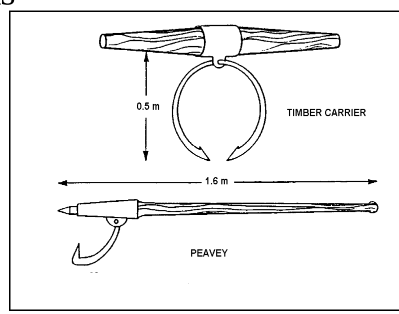

Fig 3-4-5 Peavy and Timber Carriers

PINCH AND CROW BARS

7. Pinch and crow bars are used to loosen timber, remove nails, loosen hard ground or break up masonry. They can also be used as a lever for moving heavy weights. The cutting edge is chisel shaped.

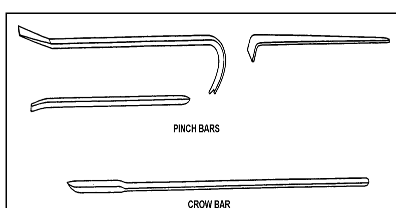

Fig 3-4-6 Pinch and Crow Bars

FILES AND RASPS

8. Files and rasps are used to shape wood or metal, and come in various sizes and lengths. A file may have teeth classified as: rough, coarse, bastard (medium coarse), second cut, smooth cut, and dead smooth grade. For fast removal of metal for rough work, the rough, coarse, and bastard files are used. For finishing, the second cut (small teeth), smooth cut (very small teeth), and the dead smooth (very fine teeth) are used.

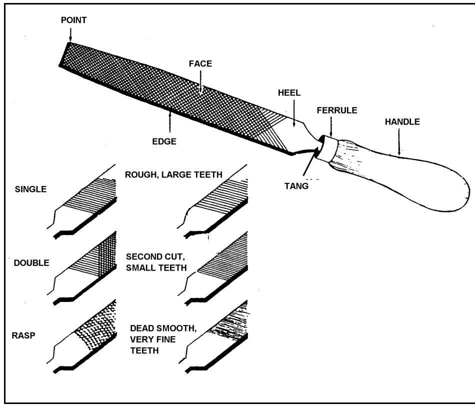

Fig 3-4-7 Files and Rasps

THUMPER

9. The thumper is a useful tool for driving steel pickets, pipes, rods and fence pickets. It is part of the demolition camouflet set.

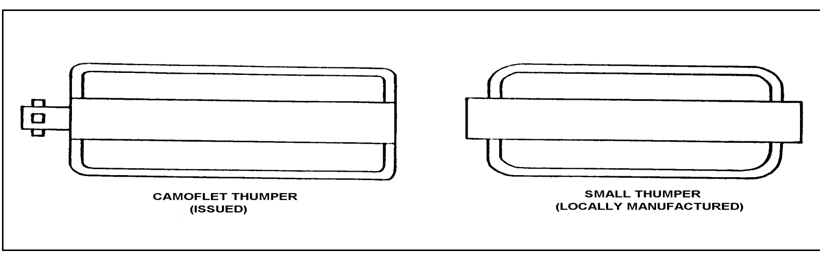

Fig 3-4-8 Thumpers

A locally produced model for driving steel pickets and smaller items can be made using a 1 m long piece of 10 cm galvanized pipe, one end capped with 1.2

cm steel and with two handles of 19 mm smooth round bar approximately 80 cm long.

RATCHET BRACE AND BITS

10. The ratchet brace is used **only** for drilling holes in wood. It turns auger bits, expansive bits, coun- tersink bits or screwdriver bits

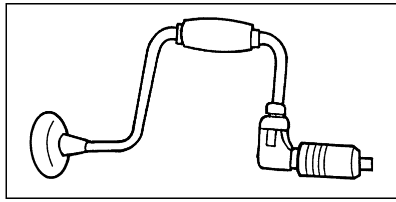

Fig 3-4-9 Ratchet Brace

11. The auger bit has a steel shaft which varies in length from 190.5 mm to 228.6 mm. It is not usually used for holes larger than 25.4 mm in diameter.

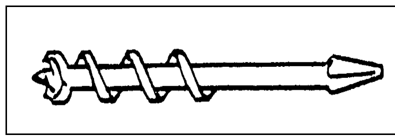

Fig 3-4-10 The Auger Bit

12. The expansive bit is used to bore holes from 12.7 mm to 76.2 mm in diameter.

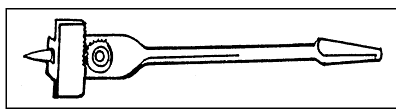

Fig 3-4-11 Expansive Bit

BREAST DRILL

13. The breast drill is used for drilling holes in metal or wood. Start holes in metal with a centre punch to help centre the twist drill. Place the drill bit at the point. Place the breast plate against the chest or shoulder; loosen the adjustment screw in the side of the plate and move the plate into a position which is comfortable, and tighten the ad just- ment screw. Set the speed shifter lever to desired speed: high or low. Hold the drill by the side handle with one hand, and apply a steady, even pressure on the breastplate. Turn the handle with the other hand.

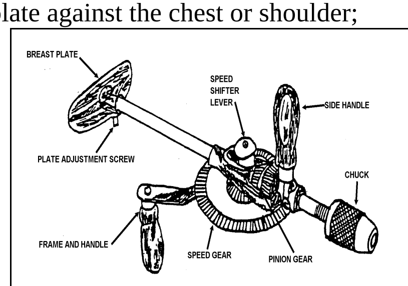

Fig 3-4-12 Breast Drill

HACKSAW

14. The hacksaw cuts metal objects of almost any size or shape, blades are 203.2 mm to 304.8 mm long, and are of two types, hard and flexible. The 18 point flexible blade, issued with the engineer tool set, is considered best for general use.

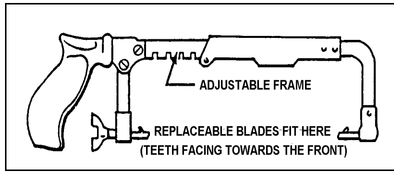

Fig 3-4-13 Hacksaw

MASONRY DRILL

15. The masonry drill is used for drilling holes in concrete or stone. It is frequently called a star drill. The cutter edges are placed in position where the hole is to be drilled and the head of the drill is struck with a heavy hammer. The drill must be rotated after each blow to clear chips to keep the drill from binding.

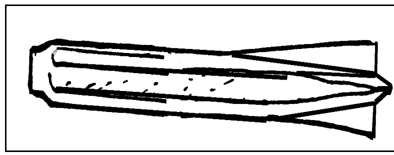

Fig 3-4-14 Masonary Drill

MEASURING INSTRUMENTS

16. The Carpenter's steel square is used to measure and mark lumber, to test the squareness and flatness of wood, to make calculations with the aid of its gradations and tables, and for many other operations. The longer arm is called the body or blade and is 24 inches long. The shorter arm is called the tongue and is 16 inches long. The side showing the manufacturer's name is called the face, the reverse side is called the back. The corner is called the heel.

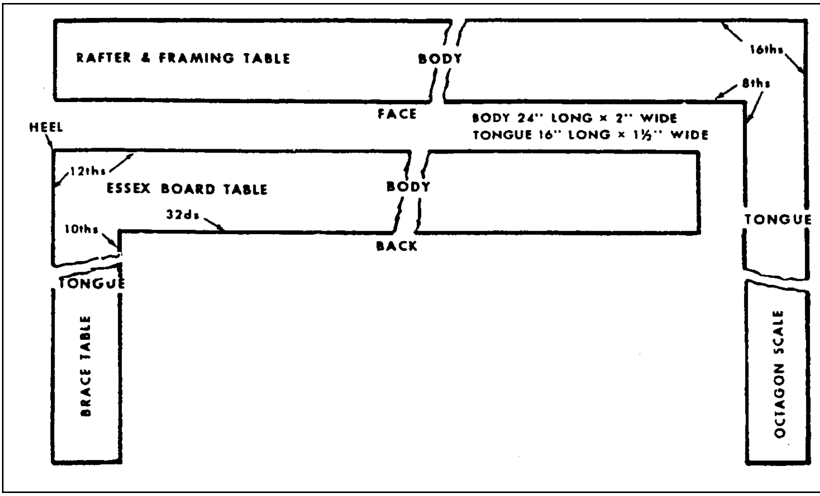

Fig 3-4-15 Carpenter's Steel Square

17. The Carpenter's level is a 24-inch wood or metal block with true surface edges. There are three bubble tubes in it, one to check for a level horizontal surface, one to check for a plumb vertical surface and the third to check a 45^{O} angle from horizontal. (Plumb means vertical or at a right angle to level.)

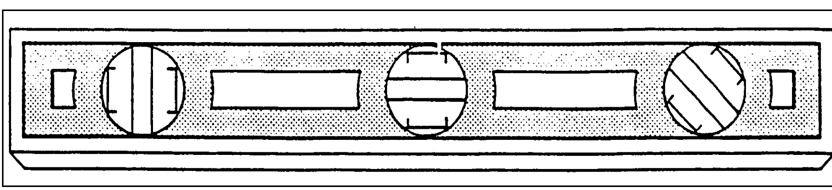

Fig 3-4-16 Carpenter's Level

18. A line level is used to check the levelness of a line between two points, as in checking the floor of an excavation. It is used in conjunction with a stretched cord. It is usually made of

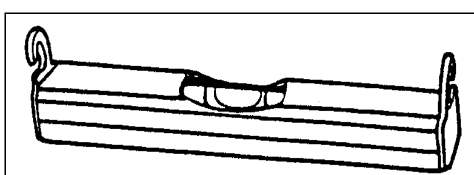

Fig 3-4-17 Line Level

Aluminum, is 76.2 mm long, has a hook at each end for hanging it on a cord, and has just one bubble tube which operates in the same manner as those on the carpenter's level.

19. The Plumb Bob is a metal weight with a pointed end. It has a device for attaching string and is used to obtain a vertical line.

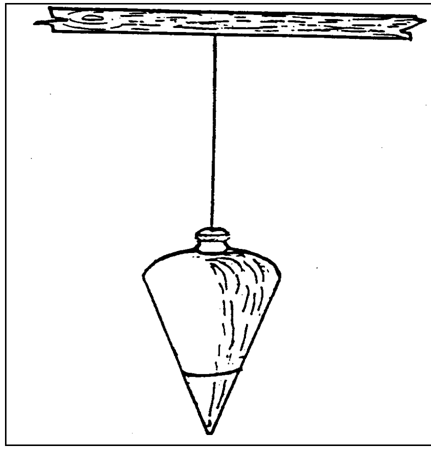

Fig 3-4-18 The Plum Bob

20. The chalk line is used to lay out a straight line between two points that are too far apart to permit use of a square or straightedge for drawing a line. It can be used for such jobs as staking foundations, laying brick, aligning walls, forms and posts and making long boards for sawing. To use:

a. tie the chalk line at the first point, pull the chalkline over the chalk, and secure the chalked line at the second point; and

b. grasp the line midway between the points and pull away at a right angle to the surface, release the line so it will snap straight downwards and deposit chalk in a straight line.

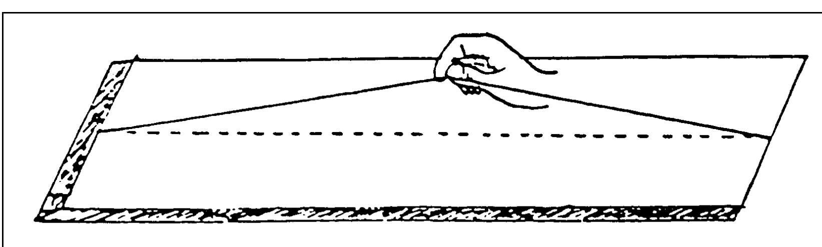

Fig 3-4-19 Chalk Line

21. The steel measuring tape is used for measuring circumference and long distances where rulers cannot be used.

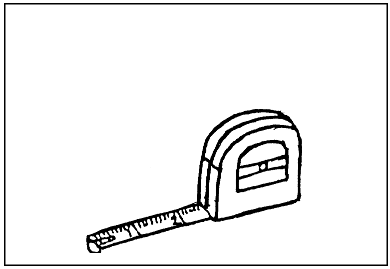

Fig 2-4-20 Steel Measuring Tape

22. The multiple folding rule is used to make measurements up to 8 feet, where precise measurement is not re- quired.

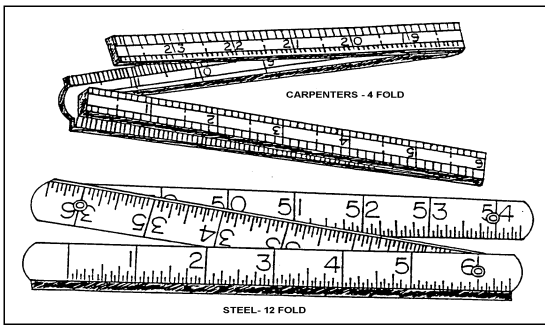

Fig 3-4-21 Multiple Folding Rule

LADDERS

23. A ladder is a piece of equipment which is used only where a more suitable means of access is impractical. The preferred ascent angle is 4 in 1 or 75 degrees to the horizontal. When using ladders, the following points shall be observed:

a. a safety person shall securet the bottom of the ladder when in use. In periods of prolonged use, the ladder will be secured top and bottom;

b. the ladder shall be placed on a firm base;

c. the ladder shall extend 1.05 m above the land-ing place un-less an equi-valent handhold is provided; and of more than nine metres.

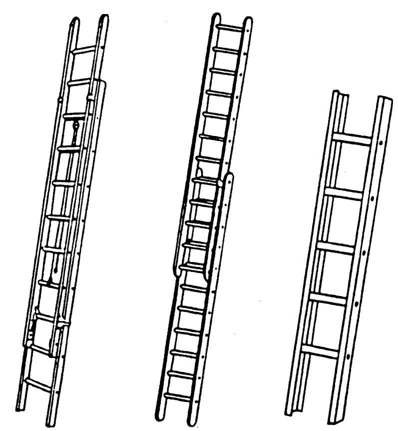

Fig 3-4-22 Ladders

TIMBER FASTENERS

24. **General.** The following fastenings for timber structures are generally available. They fall into two broad categories:

a. **Nails, Screws, Threaded Bolts and Coach Screws** are suitable for all types of light work; and

b. **Dogs, Spikes and Drift Pins** are used to connect heavy baulks of rough timber in constructions such as bridges or piers.

25. **Nails.** Nails range in size from 25 mm to 150 mm and come in a variety of types. Where possible, a nail should pass through the thinner timber into the thicker, and should be approximately three times longer than the thickness of the timber to be held in place. When nailing hardwood, the timber should be re-bored with a hole four-fifths of the nail diameter, and three-quarters of its length, and the nail should be lightly greased.

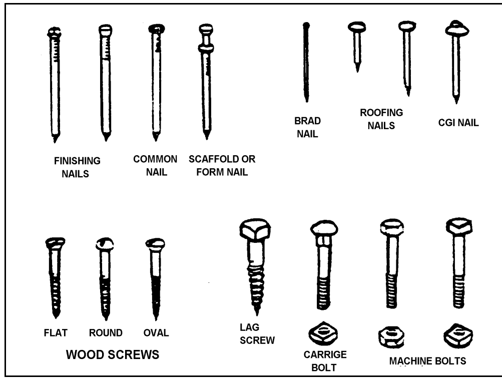

Fig 3-4-23 Nails, Screws, and Bolts

26. **Screws.** Where possible screws should pass through the thinner timber into the thicker. Holes should be bored four-fifths of the screw diameter and the screw length before insertion.

27. **Bolts.** When bolts are used to fasten timber, washers must always be used under the nut to prevent the wood being crushed and thus loosening the connection.

28. **Coach Screws.** Coach screws are used when it is impractical to use bolts and nuts. When using a coach screw, bore a hole four-fifths of the diameter of the shank for the full length of the screw, hammer it half way home and then screw tight.

29. **Timber Dogs.** Timber dogs are normally made from 10 mm square bar. They are used with heavy timber and are set so that the points are at least 75 mm from the edge or 100 mm from the end of the timber. A sledge hammer is used for driving. If the joint requires dogs on both sides, lay the frame flat on the ground, drive the dogs on the upper side halfway home, turn the frame over, and drive the dogs on the other

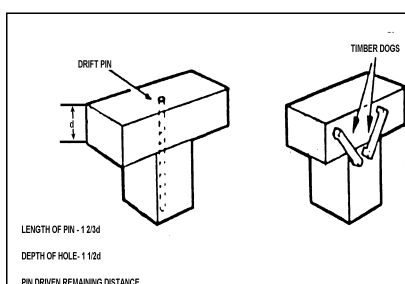

Fig 3-4-24 Timber Dogs and Drift Pins

side right home. Turn the frame over, and complete the driving.

30. **Spikes.** Spikes are large nails. They are 150 mm to 230 mm long and have a square cross-section of about 10 mm. The point is wedge-shaped and are driven with a sledge hammer across the grain to lessen the chance of splitting the timber.

31. **Drift Pins.** Drift pins are short lengths of round or square iron bar, without a head. They are driven using a sledge hammer into holes previously bored in the timber. The diameter of the hole should be about four-fifths of the bolt. The length of the pin and the depth of the bored hole depends on the thickness of the **front** piece of timber.

SECTION 5

CARE AND SHARPENING OF FIELD ENGINEERING TOOLS

GENERAL

1. All field engineering tools must be properly maintained if they are to give effective service. In most cases, this maintenance is straight forward. The basic principles are:

   a. clean and lightly oil the metal parts of tools before returning them to stores;

   b. keep cutting edges sharp at all times;

   c. maintain wooden handles and replace them when damaged;

   d. store cutting and digging tools in racks to protect their edges; and

   e. report all damages to the storeman when returning tools.

TOOL SHARPENING

2. A tool's cutting edge is wedge shaped, and for maximum efficiency it must be maintained at the correct angle. The correct cutting angle for some commonly used tools is shown in Fig 3-6-1. Cutting edges are specially hardened by a heat process called tempering. Most tools can be sharpened by grinding or filing but care shall be taken, when doing this, not to reheat them to the stage where they lose their temper.

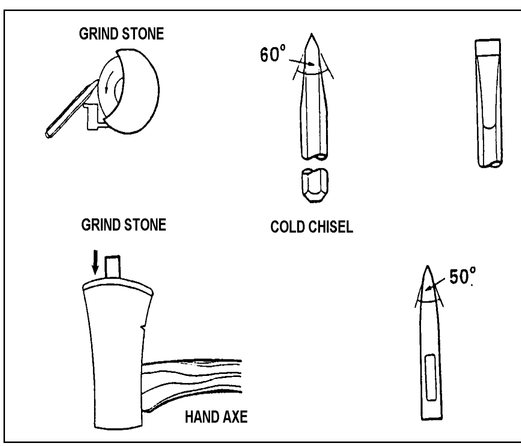

Fig 3-5-1 Cutting Angles

3. The four common types of sharpening equipment are: grindstone, power grinder, file and oilstone.

4. **Grindstone.** Although the hand-operated wet grindstone is somewhat obsolescent it is still a useful tool for cutting back large surface areas. Because the stone turns slowly in a bath of water, there is no danger of the tool edge becoming overheated.

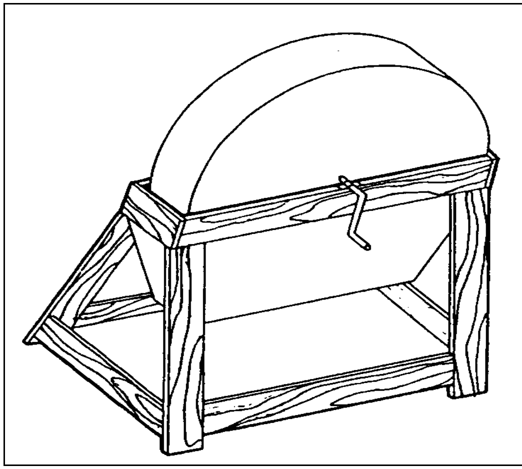

Fig 3-5-2 Hand-Operated Wet Grindstone

5. **Power Grinder.** The power grinder is a high speed grinding wheel that can be used to sharpen most tools. Use with caution; the heat generated by the speed of rotation will remove a tool's temper. Pass the edge of the blade along the grindstone and dip it in water to cool it. Eye protection shall be worn when using a power grinder. Ensure the tool rest and safety guards are properly adjusted before using.

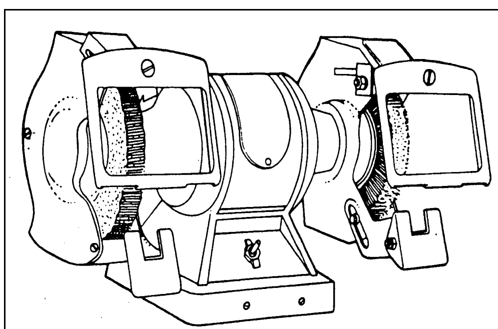

Fig 3-5-3 Power Grinder

6. **File.** Metal files are available in various sizes, shapes and grades. The file should be fitted with a handle before use, and the tool being

sharpened should have the edge cleaned and be free of oil. The sharpening stroke should be made with a combined forward and sideways motion, with the file at the right angle. As the file becomes clogged with filings, it should be cleaned with a wire brush.

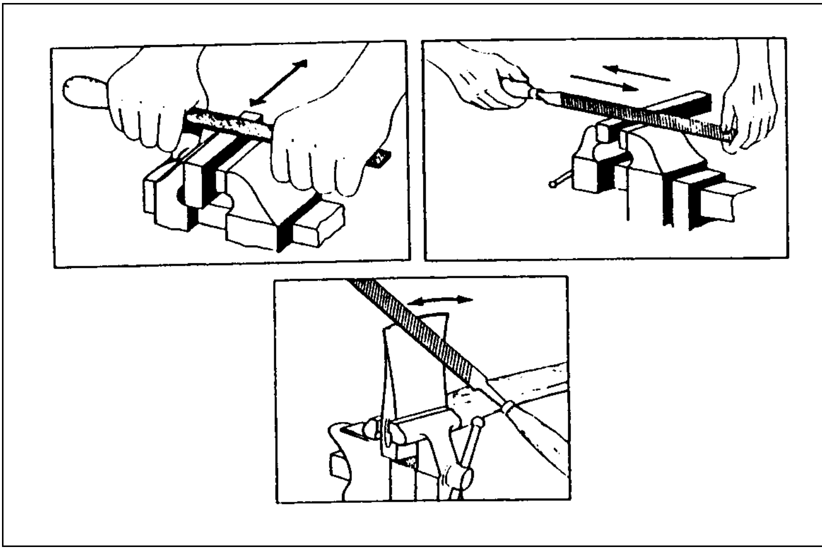

Fig 3-5-4 Correct Method of Using a File

7. **Oilstone.** The oilstone is used to put the fine edge on a cutting tool. It usually has both a fine and coarse side. The stone should be lightly oiled before use, and the whole surface should be used in the sharpening action to ensure even wear. After considerable use, the porous surface will become clogged with oil and metal particles, and its sharpening effect will be lessened. It can be reconditioned by being soaked for several hours in a solvent and then scrubbed with a stiff bristle brush.

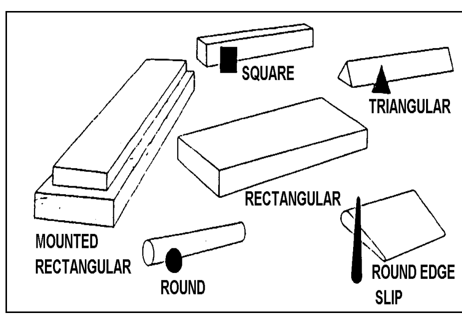

Fig 3-5-5 Oilstones

MAINTAINING AND REPLACING WOODEN HANDLES

8. The wooden handle of a field engineering tool can be a hazard if allowed to loosen or deteriorate. Replace them before this happens. Keep handles free of splinters by regularly rubbing with sandpaper, and do not paint them, as this causes blisters. Maul handles can be kept tight by soaking the head in a drum of water overnight. This causes the handle to expand and tighten in the head. For axes, hammers and sledges of all sizes, handles can be tightened by using wedges.

9. The following is the recommended method of replacing the wooden handle of a tool such as an axe:

a. remove the defective handle. This may require tapping the head away from the handle with a hammer. If it is tightly wedged the handle is sawed off near the head and then driven out using a punch, or drilled out;

b. shape the new handle using a wood rasp until it fits snugly in the tool's eye, then tap the handle with a wooden mallet to seat the head fully home;

c. saw off any of the handle projecting through the eye and finish it off flush, using a rasp; and

d. drive a new wedge (metal or wooden) into the handle and remove any of the wedge still projecting using a rasp or file as appropriate.

CARE OF THE HAND SAW

10. The two types of hand saws are the cross-cut and the rip saw. To function well, they must be kept sharpened and set periodically. The set is used to prevent the saw from binding and the angle of the set depends on the type of wood being cut.

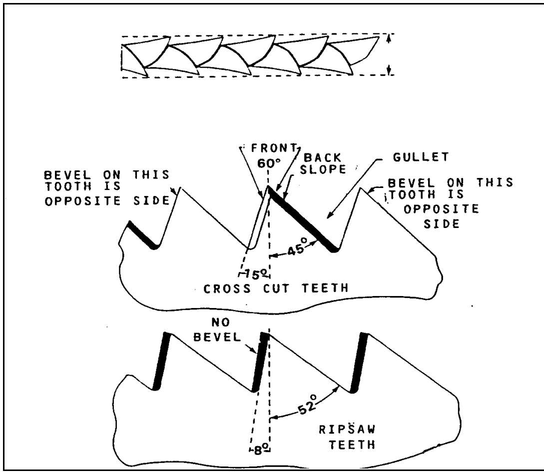

Fig 3-5-6 Difference In Cutting Edge.

11. Sharpen the saw by using a triangular file and ensure that the proper angle is kept (Fig 3-5-6). Once the saw is sharpened, the set is verified and if needed reset. This is done by using the setting tool resembling pliers (Fig 3-5-7). It has an adjustable tooth which can be adjusted to the proper angle. To set the saw teeth, start at the heel (handle end) and work towards the toe (tip), up one side, then change over and do the other side. Once the job is finished, make a test cut to ensure that it is cutting correctly.

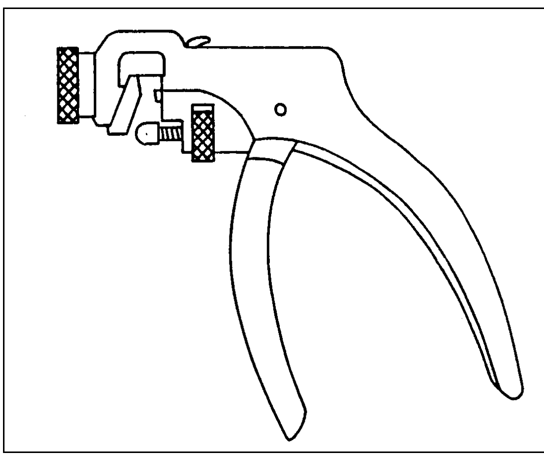

Fig 3-5-7 Set Tool

CHAPTER 4

PORTABLE POWER TOOLS

SECTION 1

GENERAL

INTRODUCTION

1. The portable power tools provided specifically for field engineering tasks are the chainsaw, Pionjar/drill/breaker and power auger. All are man portable and gas-driven. Their use increases work production; and reduces the labour and time needed to per-form a task.

2. This chapter provides a general description of these power tools, outlines their principles of operation and details common safety precautions and operating procedures. Every power tool has a technical manual and this shall be consulted prior to use for further information as required.

GENERAL SAFETY PRECAUTIONS

3. The following safety precautions are common to all power tools:

   a. know the equipment; take time to consult the operator’s manual and in particular, know the whereabouts of safety/kill switch;

   b. check the worksite for obstructions such as building overhang, tree branches, wiring of all types and before digging or drilling, check for underground electrical and communications cables and water, gas and sewer lines;

   c. dress properly, loose clothing must be removed or tucked away, and wear proper protective equipment and clothing, such as ear defenders, eye goggles, gloves, leggings etc;

   d. do not smoke while operating or refueling equipment;

   e. adopt a firm stance before using the equipment;

f. use both hands when using the equipment, and

g. maintain the equipment before, during and after use.

SECTION 2

CHAINSAWS

MAJOR COMPONENTS

1. The major components common to all chainsaws in current service use are shown in Fig 4-2-1. These are:

a. **Power Unit**. The power unit is a two-stroke, single cylinder gas engine. The moving parts of the engine rely on the oil that has been premixed with the gas for lubrication. Various manufacturers recommend different mix ratios and these should be used where possible. If the recommended mix is not known, a good compromise suitable for all makes in current use is 1 part of two-cycle engine oil to 16 parts of gas;

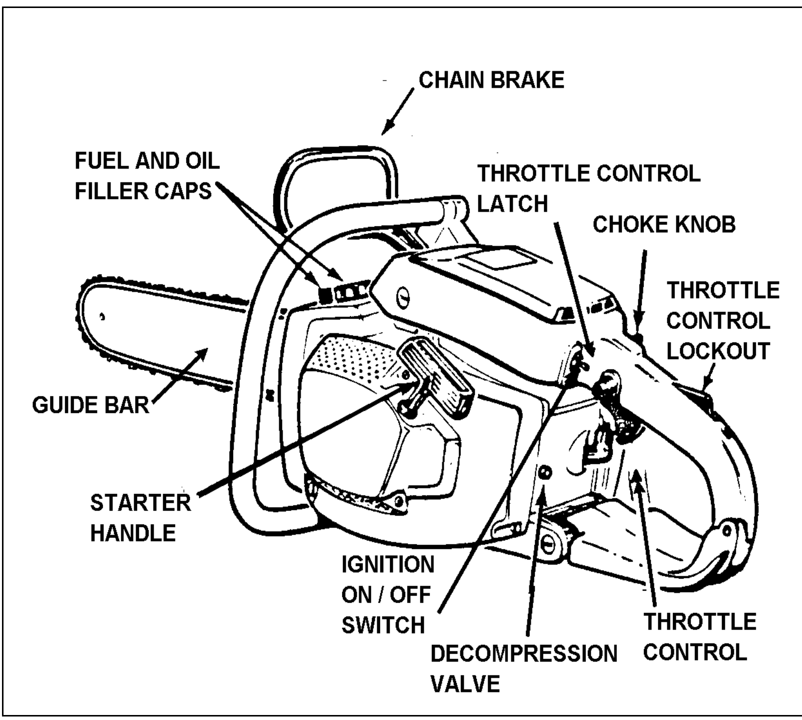

Fig 4-2-1 Typical Chainsaw

b. **Guide Bar.** The guide bar is adjustable. It provides a groove for the chain to run through and controls chain tension. There are oil passages which provide lubrication oil for the chain;

c. **Chain Lubrication Tank**. A separate oil tank is provided for chain oil;

d. **Bar Plates.** The bar plates are contoured plates of heat treated steel which guide the chain onto the guide bar. They may be separate pieces or an integral part of the chainsaw body;

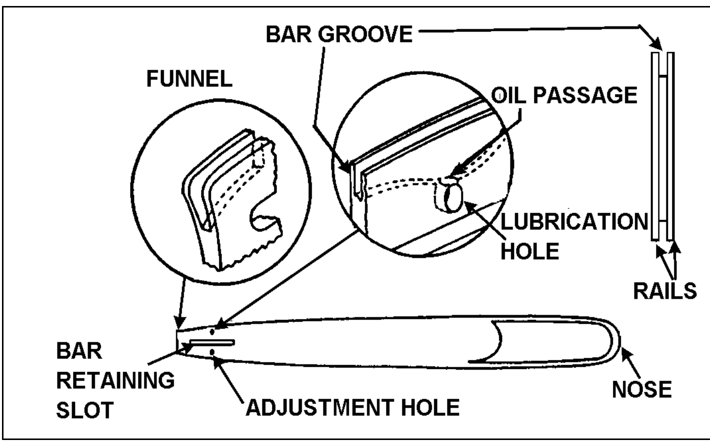

Fig 4-2-2 Parts of a Guide Bar

e. **Spiked Bumper**. The spiked bumper at the base of the guide bar is designed to be a fulcrum for the saw when making a cut;

f. **Chain Brake**. The chain brake reduces the possibility of injury due to "kickback". When the chainsaw rears up, as in a “kickback”, the chain brake comes in contact with the operator’s hand or wrist, the brake is activated and chain movement is stopped abruptly;

g. **Chain Guard**. The chain guard is a plastic cover which is placed over the chain and bar when the saw is not in use; and

h. **Pull Cord**. The pull cord is made of nylon, and is attached to a recoil mechanism. It is used to start the motor.

2. **Milling Machine**. The milling machine is a portable accessory which can be used with all standard chainsaws. It is described in Section 5.

CHAIN

3. **Sharpness.** The condition of the chain cutting links is the most important factor affecting the cutting efficiency of the saw. Malfunctions or faults in the chain will occur from time to time, but the basic cause of these will nearly always stem from the operator using a dull or incorrectly sharpened chain. The correct procedures for reconditioning and repairing chains are detailed at para 16.

4. **Tension.** Correct chain tension is another important factor that affects the cutting efficiency of a saw. Excessive tension will overload the motor, cause chain wear, stretch the chain and damage the guide bar. Tension is regulated by moveing the guide bar. Moving the bar out will increase the chain tension, moving it in will lessen it. The tip of the bar should not be allowed to drop when adjusting chain tension. Adjustment is made by turning the chain tension adjustment screw which moves the chain tension adjustment pin backwards and forwards. A chain correctly tensioned will not sag

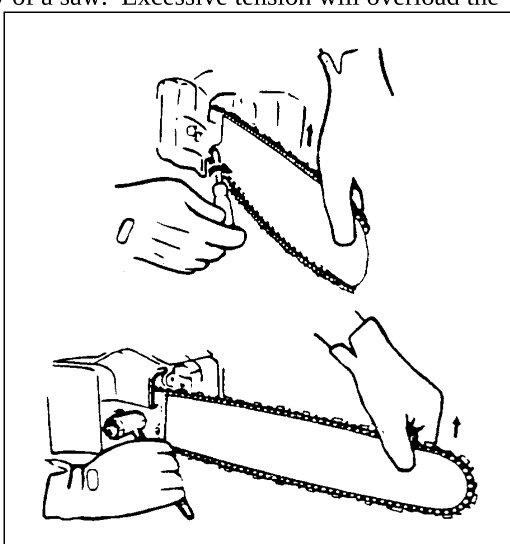

Fig 4-2-3 Chain Tension Adjustment

when cold and will rotate easily by hand.

5. **Lubrication.** The chain requires a constant supply of lubricating oil to prevent overheating and undue chain wear. This is automatically provided from the chain oil tank. The oil flows through passages in the guide bar and is then carried around the groove in the guide bar by the rotation of the chain. The oil flow adjusting screw should be set so that the usage rate for both chain lubricating oil and fuel are the same (that is both tanks are filled at the same time). Some chainsaws have a manual pump whereby the operator can inject additional lubrication to the chain during difficult working conditions.

6. **Installation.** Before handling the chain, check that the chainsaw ignition is in the "off" position. Wear gloves to protect the hands from the cutters. When a new chain is being installed, always fit a new matching sprocket. To install a chain:

a. remove the guide bar and chain from the saw;

b. hold the guide bar vertical with the tip to the top and fit the chain around it, ensuring the cutting edges face forward on the upper edge of the bar;

c. holding the chain taut on the bar, slip the chain into place fitting it on the sprocket properly. Fit the bar over the retaining bolts, making sure the inner bar plate (if detachable) is in position first;

d. fit the outer bar plate (if detachable) and the cover, and tighten the nuts finger tight;

e. hold the bar tip up, tension the chain and check to see that it is fitting properly around the bar and sprocket by pulling the chain around by hand, re-tension if necessary;

f. while still holding the bar tip up, tighten the bar mounting nuts securely; and

g. when installing a new chain, oil it thoroughly by hand.

SAFETY PROCEDURES

7. In addition to the general safety precautions for all portable tools, the following rules are to be observed when operating chainsaws:

a. never use a chainsaw unless somebody else is present;

b. carry the saw with the blade to the rear, when climbing uphill, and to the front, when going downhill;

c. check that the chain is free from obstructions before starting the motor;

d. turn off the motor to clean the saw, to check or adjust chain tension, to carry the saw, or to pass the saw to another person;

e. keep the chainsaw on the ground when starting the motor;

f. keep both hands on the chainsaw while cutting; and

g. never operate the chainsaw above chest height.

OPERATING PROCEDURES

8. The saw is designed to work at maximum revolution when cutting, and to cut under its own weight. The operator only needs to hold the saw steady and guide it through the cut. There is no point in exerting excessive pressure on the saw as each cutting link can only cut a given depth on each pass. Excessive pressure will cause the chain to run slower and reduce the work output. The following paragraphs apply to all models, but refer to the manufaturer’s operating instructions for for details particular to that model.

9. **Pre-use Checks.** The following checks should be carried out whenever a saw has not been used for some time:

a. remove the guide bar and chain and check for damage and undue wear;

b. check the drive sprocket for wear;

c. refit guide bar and adjust chain tension;

d. check oil reservoir;

e. examine high tension lead for cracks and worn spots;

f. examine air filter pad for cleanliness; and

g. tighten any loose nuts and screws.

10. **Starting Procedures.** To start the saw:

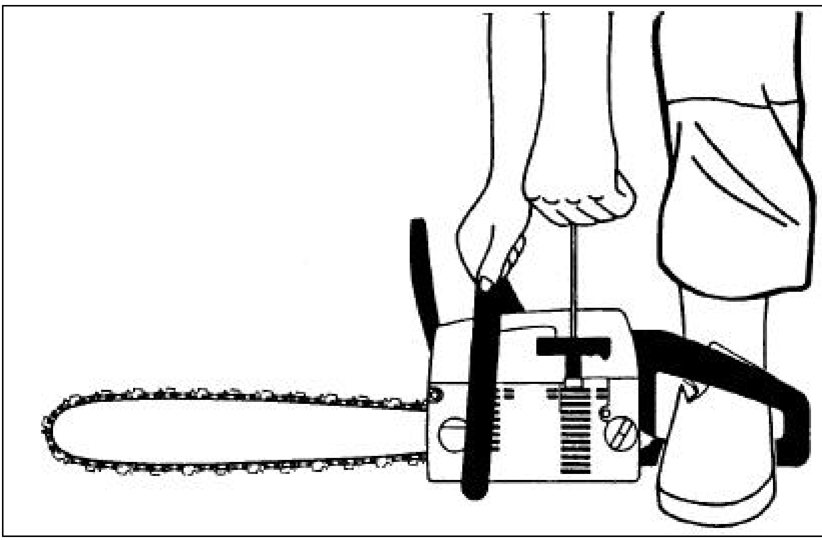

Fig 4-2-4 Starting a Chainsaw

a. place saw on the ground and switch ignition on;

b. apply choke (if motor is cold) and engage throttle lock;

c. take correct grip on saw;

d. take-up the slack in the recoil starter cord and pull the handle firmly;

e. release choke when the motor starts and disengage throttle lock by pressing the trigger;

f. run the saw for 30 seconds and check that oil is being fed to the chain;

g. switch the motor off and check chain tension; and

h. restart the saw.

11. **Stopping Procedures.** To stop the chainsaw, release the throttle and switch the ignition off. If the motor continues, run the saw into a piece of timber thus causing it to stall.

12. **Basic Operating Technique.** The chainsaw is operated with the right hand holding the pistol grip and the left hand grasping the handle. The chain must be rotating freely at maximum revolutions. The base of the chain is then laid on to the timber with the guide bar pointing slightly upwards (Fig 4-2-5). The cutting action of the chain will pull the saw forward so that the sprags bite into the timber. The sprags then act as a fulcrum while the saw is pivoted downward.

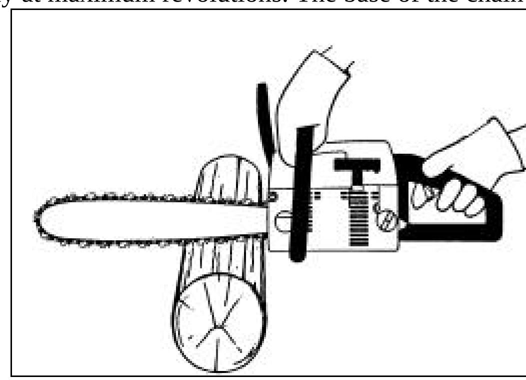
Fig 4-2-5 Starting a Cut

13. **Chain Break-in Procedure.** Any new chain will wear or "stretch" in use, the greatest wear occurring during the first half-hour of operation. Following the proper break-in procedure, when the chain is new can reduce the amount of initial wear and extend the useful life of the chain. To break in a new chain:

a. install the chain correctly and start the engine;

b. run the engine at one third throttle for at least two minutes ensuring the chain receives a constant liberal supply of oil (if it has a manual pump, inject oil every five seconds);

c. stop the saw and retension the chain as necessary;

d. run the engine at half throttle (again not cutting anything) for three minutes ensuring a liberal supply of oil and then recheck tension; and

e. make several light cuts still using excess oil and keep a close watch on tension.

MAINTENANCE

14. Correct maintenance after use is essential if chainsaws are to be kept in good working order. Refer to the manufacturers's maintenance manual. Inspect regularly and report any damage immediately. General servicing procedures are:

a. remove the chain and guide bar;

b. thoroughly clean all components;

c. inspect the motor, sprocket and guide bar for any damage and correct if possible; and

d. clean the air filter.

15. **Guide Bar Maintenance**. A well maintained guide bar is most important for the efficient functioning of the chain. Maintain the guidebar as follows:

a. inspect and clean the bar channel regualrly; it can become fouled with sawdust and then impede the chain;

b. smooth, by filing down, the bar rails which hold the chain upright; they can scar and become burred over in heavy use;

c. replace a bar with worn or spread rails. To check, place a straight edge against the side of the bar and one cutter. If there is clearance between the bar and cutter the rails are in good condition. If the chain leans, and there is no clearance, the rails are damaged;

d.

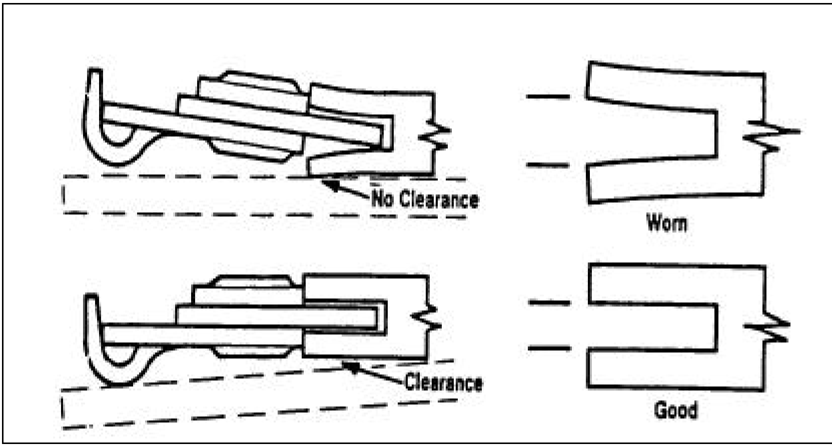

Fig 4-2-4 Checking for Spread Bar Rails

d. keep all oil passages clean and the bar tip properly lubricated. It usually has two lubrication holes, one on each side of tip; and

e. turn the bar over regularly to ensure even wear.

CHAINSAW CHAIN RECONDITIONING AND REPAIR

16. The life of a chain depends a great deal on how it is maintained. It must be kept in good condition and any damaged parts replaced or reconditioned before further damage can occur. A chain consists of several components as shown below.

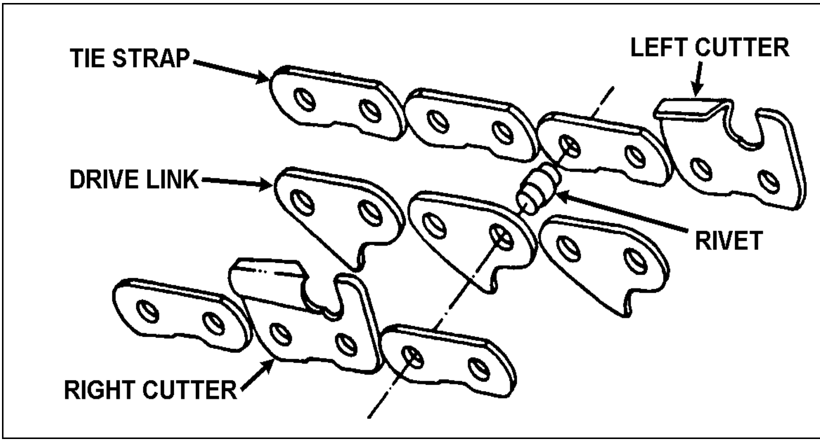

Fig 4-2-7 Parts of a Chain

TYPES OF CHAIN

17. There are many types of wood and there are many types of chains. The most common are:

a. **Standard chain** - the most popular, it combines fast cutting action with ease of filing

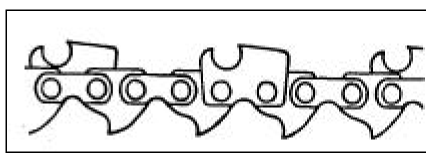

Fig 4-2-8 Standard Chain

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b. **Safety chain** - a standard chain with a safety contoured side link to protect against "kick-back

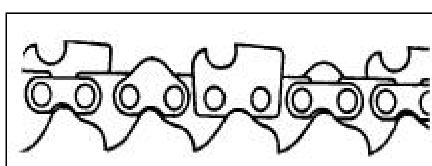


Fig 4-2-9 Safety Chain

c. **Ripping chain -** a chain designed to make ripping cuts. It is similar to a standard chain but is filed at a 90^{o} angle. It is ideal for use with the milling machine

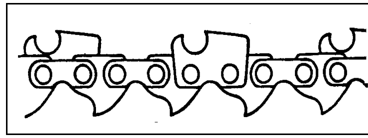


Fig 4-2-10 Ripping Chain

RECONDITIONING CUTTERS

18. To cut wood effectively, the cutters must be kept in good condition. This is accomplished in two steps:

a. the cutting faces are re-set and re-sharpened by filing; and

b. the depth gauges are re-set and re-shaped by filing.

When reconditioning is complete, the chain shall be cleaned to remove metal filings.

SHARPENING ANGLES

19. There are various angles depending on the type of chain being used. The common standard chain (Fig 4-2-8) has:

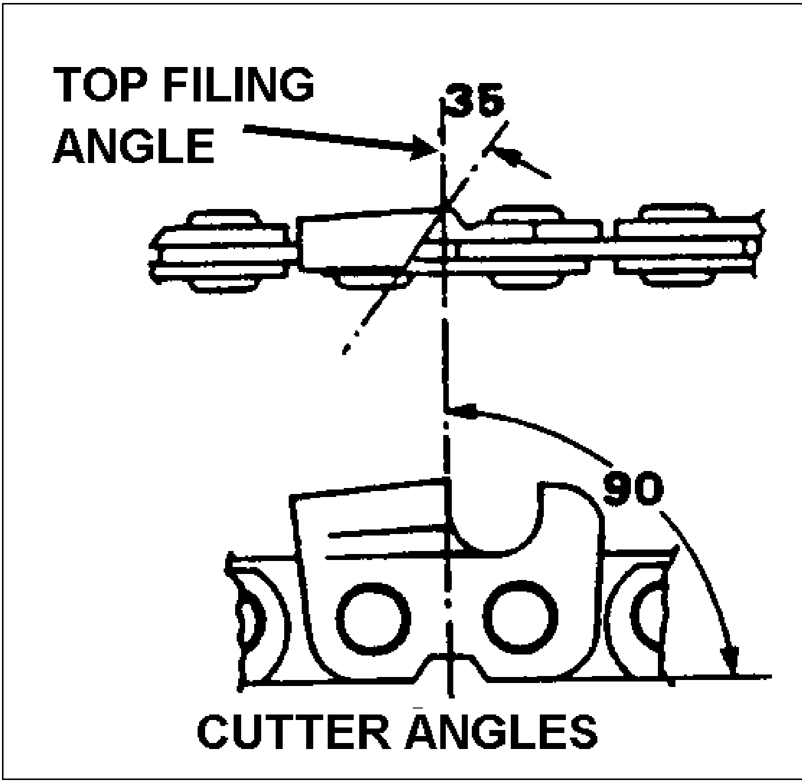


Fig 4-2-11 Sharpening Angles

a. top plate filing angle - 35 degrees; and

b. side plate angle-90 degrees.

DEPTH GAUGE SETTINGS

20. The depth gauge controls the amount of wood a cutter can remove in one pass. The gauge may vary between 0.06 mm for cutting hardwood to 0.09 mm for cutting softwood. Most new chains come with the chain gauged to 0.08 mm, which is a good general cutting gauge. The tools required for depth gauge setting are:

a. depth gauge tool (with settings stamped on it); and

b. second cut flat file.

SHARPENING CUTTERS

21. Cutters can be sharpened with either a round steel file or a specially designed power grinder. The files are used with a file guide. The cutters in the worst condition are sharpened first and the other cutters are then sharpened to match. All filing is done on the same position on the bar to compensate for any variations along the bar. The following points shall be taken into account when sharpening cutters:

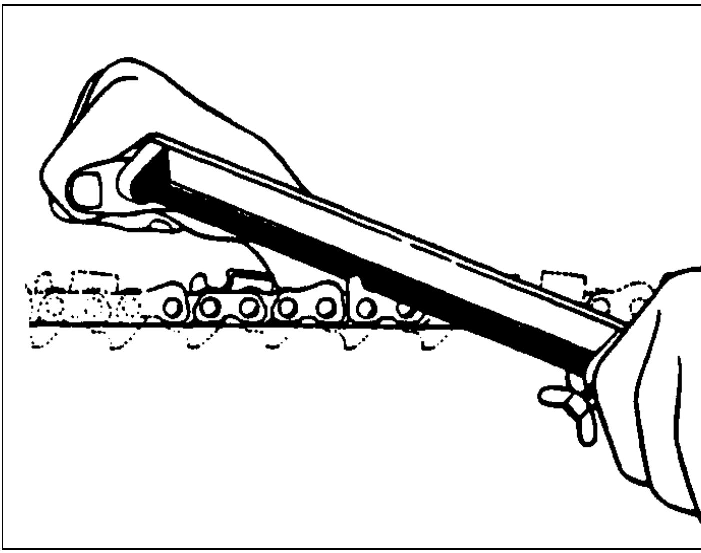


Fig 4-2-12 Using a File Guide

a. use correct file and file guide;

b. make the filing stroke in one direction, from inside of cutter outwards with a steady firm pressure

c. apply same number of filing strokes required to sharpen the worstcutter to the remainder.

USING THE FILE GUIDE

22. When using a file guide:

a. lay file guide on top plate of a cutter so that filing angle marks are parallel to the chain;

b. make each filing stroke with the guide handle horizontally at the same level as the top plate. This ensures 90° filing angle is maintained; and

c. continue filing until all wear has been removed.

SETTING THE DEPTH GAUGE

23. To set the depth gauge, place the depth gauge tool on the cutter with the gauge projecting the slot in the end of the tool. File the projecting top of the depth gauge down to the surface of the depth gauge tool and round off the front of the depth gauge to its original shape. If the depth setting is too large, the cutting faces is cut further back to reduce the difference in height.

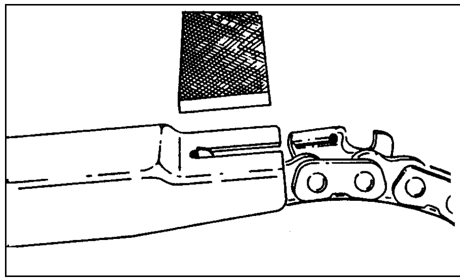


Fig 4-2-13 Setting the Depth Guage

PROBLEM SOLVING

24. Common filing errors are:

a. **Too Great**. Too large a top plate filing angle is caused by holding the file at the wrong angle. It results in a thin, sharp side plate which tries to pull the cutter sideways in the wood. This makes the chain wobble and causes a wider cut. This wobble also causes the upper portion of the centre link tangs to wear against the inner edge of the bar rails thus damaging to the drive link tangs and the bar groove. If the top plate angles are uneven as well as too great, the wear will be even worse. If the top plate angle on a skip tooth chain is too great, the cutters can pull far enough towards each side to leave an uncut ridge of wood in the centre of the cut.

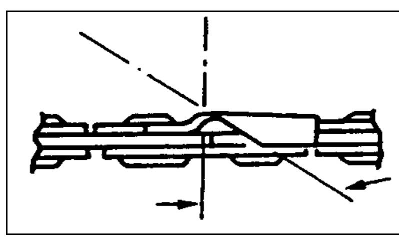


Fig 4-12-14a Too Great

b. **Too Small.** Too small a top plate angle is caused by holding the file at the wrong angle. It results in a blunt side plate; the chain will not feed into the wood and will require more pressure to cut. This additional pressure will wear the bar rails, bottoms of the side links and cutters at their heels. The chain will also chatter which causes loose rivets and the eventual breaking of the chain at a heel rivet hole.

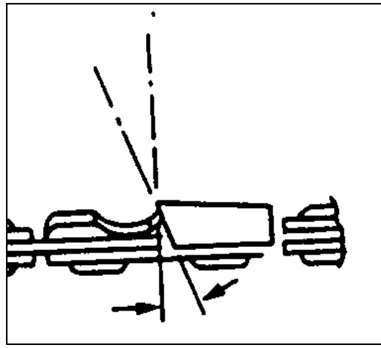


Fig 4-2-14b Too Small

c. **Hooked.** A hooked cutter is caused by using too small a file or not holding the file horizontally (handle end too high). It results in a chain that feeds and cuts fast for a short time. It then becomes blunt and will not cut unless pressure is applied to the bar which causes excessive wear on the bar rails and cutter.

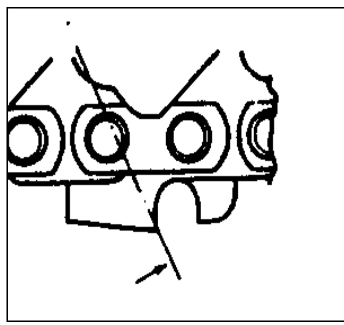


Fig 4-2-14c Hooked

d. **Back Slope.** A back-sloped cutter is caused by using too large a file or not holding the file horizontally (handle end too low). The cutter is dull, will not feed into the wood, chatters and bounces, and requires heavy pressure. This causes bar, tie strap, and cutter wear, and eventually a broken chain.

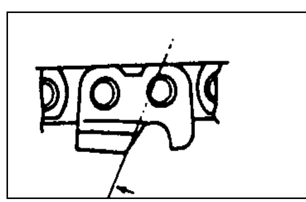


Fig 4-2-14d Back Sloped

d. **Filled In.** A filled-in gullet is caused by not removing the metal in the gullet with a small round file. This reduces chip clearance and slows cutting.

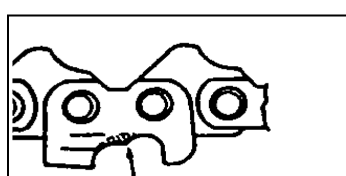


Fig 4-2-14e Filled In

f. **Too High**. Too high a depth gauge setting prevents the top plate from cutting the wood. Heavy pressure is required to make the chain cut. This results in excessive wear on the bar and at the top of the cutters, and eventually, a broken chain.

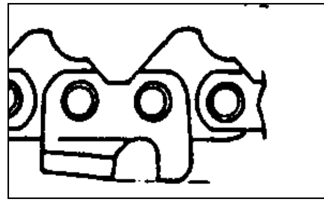


Fig 4-2-14f Too High

g. **Too Low.** Too low a depth gauge setting permits the top plate to cut too much wood and lets the cutter chatter or bounce. The overall result will be loose rivets, wear on the heels of the cutters, and a broken chain.

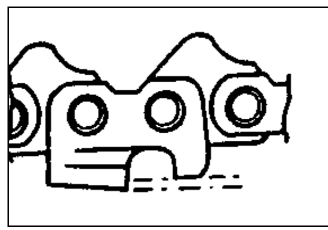


Fig 4-2-14g Too Low

h. **Too Blunt**. A flat- topped depth gauge will hammer into the wood and make the top plate cut too much wood as it enters the cut. The chain will run very roughly and develop loose rivets.

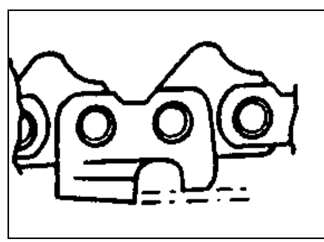


Fig 4-2-14h Too Blunt

CLEANING

25. A chain shall always be cleaned after reconditioning to remove any filings which may have adhered to the oil. The chain can be cleaned by slowly running the chain while pumping the oil to the chain. Occasionally a chain may need cleaning in order to remove any resin which has accumulated in the chain. To remove the resin, take off the chain and soak it in a solvent for several hours or until the resin has dissolved. When the chain is taken out of the solvent bath, it must be cleaned with a soft brush, and then re-oiled.

FIELD REPAIR

26. The field engineer shall be able to carry out basic operator maintenance to ensure maximum use. Refer to the manufacturer's maintenance manual to:

a. break and make chain;

b. replace air filter;

c. replace sparkplug; and

d. replace starter cords.

EXTENDED STORAGE

27. When placing a chainsaw in extended storage, ensure:

a. the fuel and oil reservoirs are emptied and run dry;

b. a light coating of oil is applied to the bar and chain; and

c. the combustion chamber is oiled by:

(1) removing spark plug and placing a teaspoon of ASE 110 in the chamber,

(2) pulling recoil starter at least twice, and

(3) replacing the spark plug.

SECTION 3

THE PIONJAR DRILL/BREAKER

GENERAL

1. The Pionjar is powered by a single-cylinder, air-cooled, two-stroke motor with reverse flow scavenging. The machine operates according to the opposed piston principle - both motor piston and hammer piston work in the same cylinder. Compression and ignition take place between the two pistons. The motor piston is connected via the connecting rod to the crankshaft unit and flywheel. The hammer piston runs freely in the cylinder and its working cycle is automatically synchronized

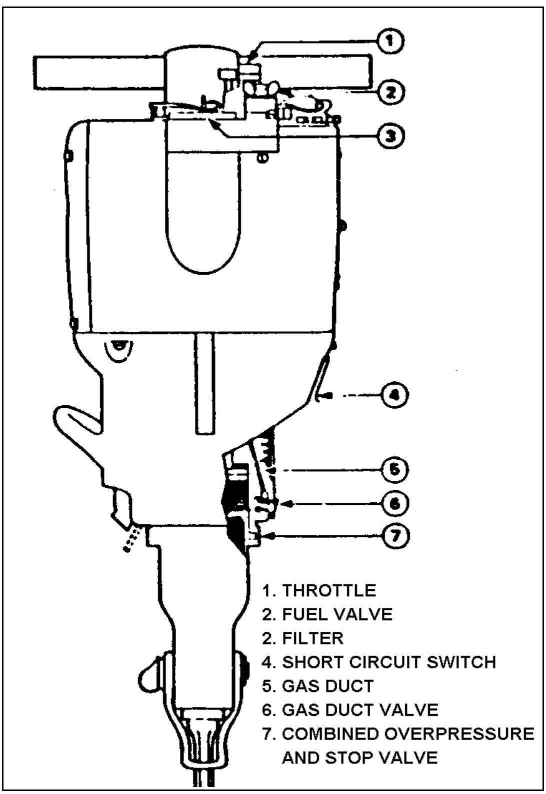


Fig 4-3-1 Design and Function of the Main Components of the Pionjar

TOOLS AND ACCESSORIES

2. The Pionjar comes with a wide variety of tools and accessories. For back-packing, it has its own carrying harness with frame, which can carry two bits. There is a case constructed of wood, which allows for easy and convenient storage. Some of the tools which come with the Pionjar are:

a. chisel bit (in varying lengths: 0.61, 1.22, and 2.44 m);

b. drill with cross bit;

c. mole point;

d. asphalt chisel;

e. narrow chisel;

f. straight spade; and

g. compactor.

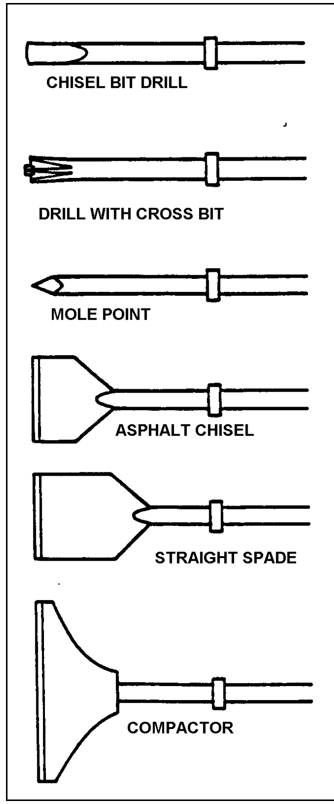


Fig 4-3-2 Pionjar Tools

3. Pionjar attachments are the grinder, wood bit auger, and hose assembly exhaust extension.

OPERATING INSTRUCTIONS

4. The operator shall consult Technical Order C-96-145-000/MG-000. To operate, ensure the fuel tank is full (1.9 litres) with a mixture of oil and gas to a ratio of 1:12. **IMPORTANT:** Never use ready-mixed two-stroke fuels; this mixture gives insufficient lubrication in the lower part of the machine. Open the fuel needle valve, close the choke completely, turn throttle to full, close stop valve, prime engine, open choke

fully and pull the starter wire. To stop the engine, press the leaf spring over the spark plug. For longer stops, close the fuel valve clockwise (Fig 4-3-1).

SAFETY PRECAUTIONS

5. The following safety precautions, in addition to those listed in Section 1, shall be observed when using the Pionjar:

a. never operate the Pionjar alone;

b. ensure the tool is free of excess oil;

c. attach the tool prior to starting the engine;

d. never operate 45° above the horizontal; and

e. for indoor operation, ensure the exhaust hose is attached.

MAINTENANCE

6. **Daily Maintenance**. The Pionjar is almost soldier-proof and requires minimal maintenance. However, two mearsures which will be carried out daily are the cleaning of the air filter and gas duct. Refer to manual C-96-145-000/MG-000 for detailed instructions on daily maintenance.

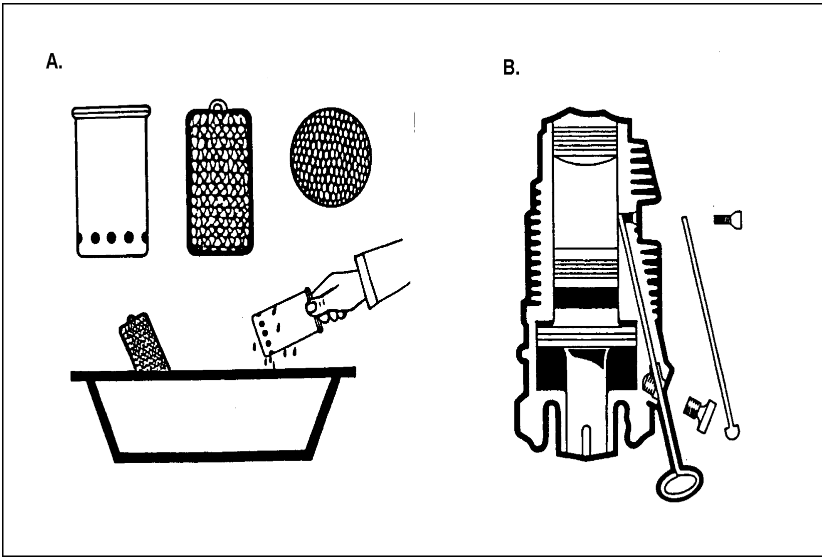


Fig 4-3-3 A - Air Filter Cleaning and
B – Gas Duct Cleaning

STORAGE

7. Prior to long term storage, drain it of fuel, run it dry, lightly oil all the attachments, and then store the Pionjar in its wooden container.

SECTION 4

POWER AUGER

GENERAL

1. The power auger is designed to use a variety of attachments ranging from wood boring bits to 150 mm earth boring augers. The common service model also has a 100 mm ice auger in three sections of one metre each. For complete specifications, consult the manual C-96-153-000/ MB-000, boring tool. STIHL 4309.

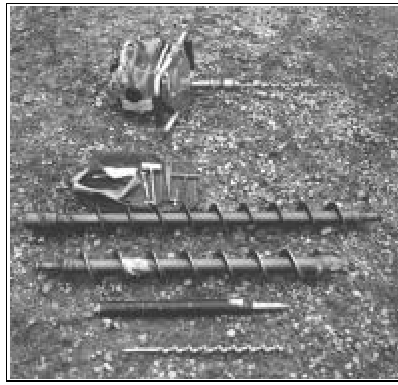


Fig 4-4-1 Stihl 4309 Power Auger

SAFETY PRECAUTIONS

2. In addition to the general safety instructions for all power tools at Section 1, personnel using the power auger shall be careful to:

a. adopt a safe and firm foot hold and hold the boring tool firmly to parry sudden jerks;

b. keep personnel out of the reach of the boring tool; and

d. do not touch the auger and spindel until the engine has stopped; and

e. cover and secure drilled holes.

OPERATING INSTRUCTIONS

3. To operate the power auger:

a. check the throttle trigger before starting motor. Engage and then release the throttle trigger. When the throttle trigger is released, it must immediately return to the idle position;

b. insert the boring tool into the boring spindel, before starting the drive motor;

c. do not use augers longer than 800 mm;

d. when boring in ice and earth combination, speed thrust has to be reduced to a minimum, and

e. lift auger out of hole evenly and horizontally, so as not to tilt the auger.

MAINTENANCE AND STORAGE

4. Prior to storage, all fuel shall be drained and the tool maintained. If possible, the auger is to be stored in an upright position.

SECTION 5

MILLING MACHINE

SPECIFICATIONS

1. Consult C-96-011-OOD/ME-000 Equipment Description and Installation and Assembly Instructions for the Alaskan MIL 111 Milling Aid NSN 3695-21-879-7144.

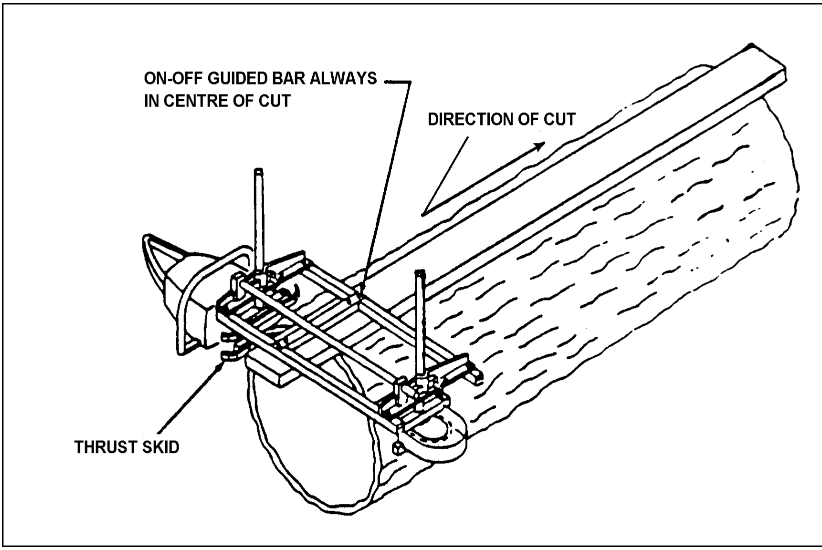


Fig 4-5-1 Milling Machine

2. The milling aid is used to provide rough sawn timber and is attached to a standard chainsaw. The components of the milling machine are:

a. roller;

b. slab rail;

c. helper handle with roller;

d. auxilliary oiler (not on all models); and

e. one double end bar for saw is required.

SAFETY PRECAUTIONS

3. The general safety precautions for power tools and for chainsaws shall be followed.

OPERATING INSTRUCTIONS

4. The operation of the milling machine requires no special tools or alterations. A ripping chain will achieve best results when using the milling aid. Once attached to chainsaw, the roller and slab rail are adjusted to desired thickness.

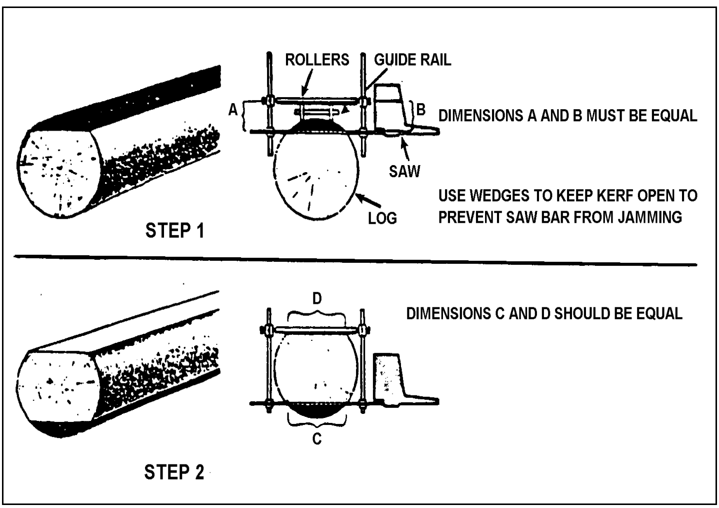


Fig 4-5-2 Using the Milling Machine

STORAGE AND MAINTENANCE

5. Prior to storage, the milling machine must be cleaned to ensure all moving parts are free running and not damaged. The milling machine is stored in its own box.

CHAPTER 5

COMPRESSOR AND COMPRESSOR TOOLS

INTRODUCTION

1. This chapter provides a general description of compressors and compressor tools, with general operating hints, and an air requirement table for various tools and safety precautions. A compressor draws air from the atmosphere and compresses it with a motor-driven pump. It then stores the compressed air in a tank before it is drawn off, as required, to power any attached tools.

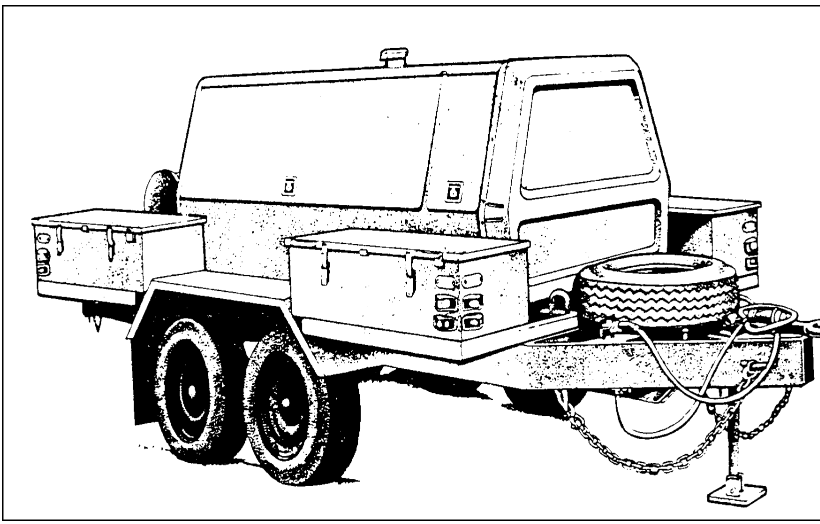


Fig 5-1-1 Typical Compressor

2. Compressors are being replaced for the most part by hydraulic systems, however field engineers must remain familiar with compressor operation.

SAFETY PRECAUTIONS

3. The following safety precautions are to be observed when using a compressor and tools:

a. dress properly, wear eye and ear protection and tie or tuck in loose clothing;

b. safety personnel shall be positioned by the air cocks at the rear of the compressor when a tool is being used;

c. keep all hose connections tight;

d. ensure that the tool is fully under control before turning on the air supply;

e. use both hands to operate all tools;

f. never direct a stream of compressed air at another person;

g. do not use compressed air to clean dust from clothing or hair;

h. always cut-off and drain the air supply when connecting or disconnecting a tool.

COMPRESSOR COMPONENTS

4. The main components of a compressor are the motor, the compressor unit and the receiver.

5. **Motor.** The motor that drives a compressor may be gas, diesel or electric. All are fitted with a governor which varies theengine speed according to the demand for compressed air; the greater the demand the faster the engine speed.

6. **Compressor Unit.** The compressor unit produces a variable volume of compressed air at a constant pressure, usually 100 lb/in^2 (46 kg/cm^2), the output being directly proportional to the speed of the motor. The maximum output of a compressor unit governs the type and number of tools that can be operated simultaneously, as each tool requires a certain volume of air to power it. For maximum efficiency, the tools must be operated at the normal discharge pressure of the compressor. Many compressor units are cooled during compression by the injection of oil into the air being compressed. This oil also provides the lubrication for the compressor unit. Most of the oil is recycled but a small quantity is carried out of the compressor unit in the compressed air and provides limited lubrication for the air motor in any attached tool.

7. **Receiver.** The receiver is a specially made tank which stores the compressed air and evens out any pulsations. In many compressors it also serves as an oil separator to remove the oil injected into the air during compression. In this case, it is termed a receiver separator. The oil collects in the receiver separator and is then pumped to a special radiator where it is cooled prior to being re-used.

TOOLS AND ACCESSORIES

8. **Air In Line Lubricator.** The air in line lubricator (Fig 5-2) must be used with all compressor tools. It meters a supply of lubricating oil to the air motor of the tool.

a. **Types of In Line Lubricators**. The two types of lubricators in use are a one litre and a 0.5 litre, directional and non-directional. The arrow on the oiler shall point towards the tool, and if no arrow appears on the oiler, the filler plug should go towards the compressor. The lubricator is attached to the air line between 3 and 7.5 m away from the tool.

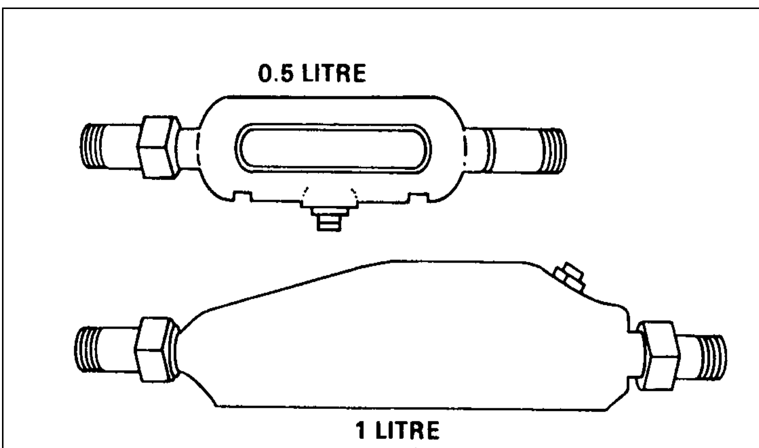


Fig 5-2 Air In Line Lubricator

b. **Adjustment**. The adjustment of the flow of oil is made by turning the adjustment screw located below the filler plug in the oil reservoir. To obtain correct adjustment, connect the air line lubricator into the air line and start the compressor. Using a screwdriver, turn the adjusting screw, until a light film of oil can be seen in the air at the free end of the hose.

c. **Types of Oil**. The type of oil used in the air in line lubricator is number 10 oil. Normally in summer conditions the adjustment screw is set on five, but this may be adjusted as necessary.

9. **Heavy Breaker.** The heavy breaker is used for breaking-up rock, road surfaces and mass concrete, for tamping loose surfaces, and for driving drift pins and light piles. It can be used with a maul point, tamper, spike driver or pile driver.

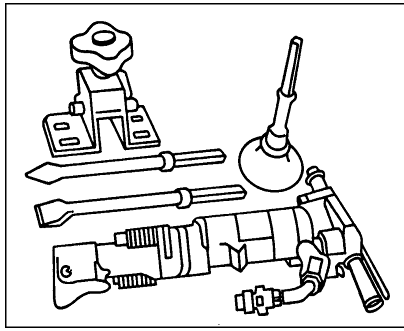


Fig 5-3 Heavy Breaker

10. **Rock Drill.** The rock drill has a combined percussive and rotary action, and is used together with a drill stem and bits, for drilling holes in rock, concrete and masonry. It is fitted with a clutch lever to engage the rotary action, and a compressed air control lever. When the compressed air lever is actuated by the operator, the drill stops and the full amount of compressed air being delivered to power the tool is directed down the hollow drill stem to clear the hole of rock dust. The drill hole shall be blown free of dust, at regular intervals, to prevent the drill bit seizing. Use as a guide, a maximum interval of 30 seconds or 10 cm of depth. Drill stems and bits are described as follows:

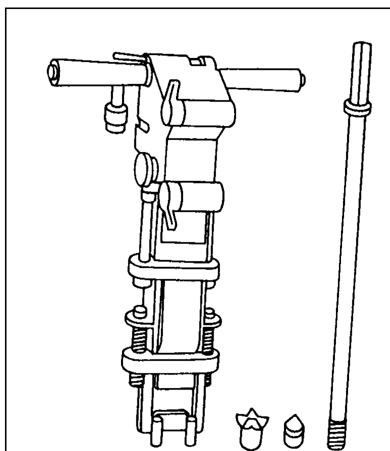


Fig 5-4 Rock Drill

a. **Drill Stems**. Drill stems used with the rock drill range in length from 0.7m to 3.8m. They have a hole running their full length to allow the passage of compressed air. Inspect the stem before use to ensure it is straight.

b. **Drill Bits**. Drill bits have either cruciform or chisel-shaped cutting edges and are screwed on the drill stem which has a left hand thread. The compressed air outlet hole normally runs centrally through the bit. Special bits with air outlets on the side is used in wet conditions where the rock dust is likely to form a plate that would block a central hole.

11. **Light Pick**. The light pick is used in a similar manner to the heavy breaker, but on work of a lighter nature. It is most useful for breaking soft rock or digging clay. It can be used with a maul point, a chisel point, a spader or a drift bolt set.

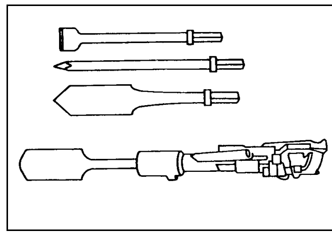


Fig 5-5 Light Pick

12. **Pneumatic Saw.** The pneumatic saw is used for cutting timber up to 100 mm in depth. Weekly servicing consists of lubricating the two grease-points using a low pressure grease gun. Once a month, the air filter shall be removed by unbolting the handle from the motor housing and washing it in solvent.

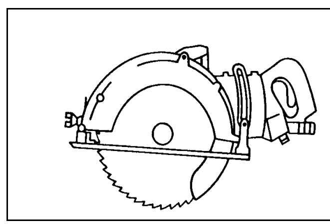


Fig 5-6 Pneumatic Saw

13. **Sump Pump.** The sump pump can be used to pump most liquids. Its main application, however, is for pumping water without being susceptible to blockage. It has a maximum capacity of 13 500 litres per hour to a total head of 15 m. Weekly servicing consists of lubricating the two grease nipples using a low pressure grease gun. A special cold water pump grease is used rather than a standard or automotive water

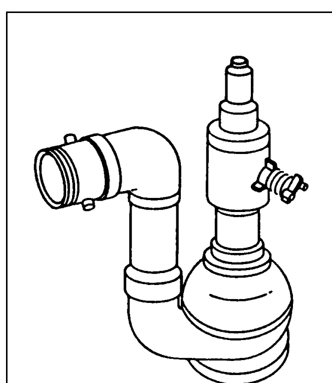


Fig 5-7 Sump Pump

pump grease. Once a month the air filter is cleaned by unscrewing the air filter plug and turning on the air momentarily to blow out dirt. If this method proves inadequate, unscrew the air strainer cap, remove the filter and wash in solvent. Check the following points when operating the sump pump:

a. the exhaust extension shall always be above the level of the liquid;

b. avoid operating the pump at free speed (unsubmerged) for lengthy periods; this causes frictional heat and damages seals; and

c. prevent, as much as possible, excess silt or mud entering the pump by seating it on a board or flat stone.

OPERATING HINTS

14. **Cleanliness.** It is particularly important to keep all surfaces of a compressor clean. This will help keep the operating temperature down, allow the gauges to be read, and identify any oil leaks quickly. The gauges shall be closely monitored as they provide early warning of approaching trouble.

15. **Pre-Start Lubrication.** Before connecting the air line to any of the previously described tools, a small quantity (about 5 ml) of oil should be inserted into the tools air intake. This provides immediate lubrication to moving parts.

16. **Engine Problems.** If the engine stops, do not restart it immediately. Determine the cause, and restart the engine only if it can be corrected. Similarly, if the engine misfires, shut it down immediately and determine the cause before continuing work. A particular problem with diesel engines is the tendency to run backwards which is caused by stopping the engine while it is under load or by not allowing the engine to cool down sufficiently. Running backwards is detrimental to the engine and if it occurs, the engine shall be stopped immediately by pulling the stop handle. A sign of the engine running backwards is the exhaust outlet flap remaining closed.

17. **Cold Weather Precautions.** Anti-freeze solution is to be added to the cooling system in conditions where overnight temperatures are likely to cause freezing. If not available, drain the radiator and engine completely at the end of each day's work and refill prior to starting.

18. **Tool Matching.** The CompAir Ford diesel compressor has an output of 100 lbs/in^2 (46 kg/cm^2). Each tool has a maximum air usage rate and the air in line lubricator, hoses and other fittings lose air which can be equated to a usage rate given in Fig 5-8. To determine the feasability of a combination of tools, the usage rates for the tools, hoses and fittings are simply summed and compared to the compressor output.

Compressor Tool	**Compressed Air Usage Rate**	
	ft^3/min (CFM)	*m^3/min*
Heavy Breaker	40	1.13
Light Pick	35	0.99
Rock Drill	50 - 80	1.41 - 2.26
Pneumatic Saw	55	1.55
Sump Pump	50	1.41

Fig 5-8 Air Usage Rates of Compressor Tools

CHAPTER 6

HYDRAULIC POWER SUPPLY SYSTEMS

AND HYDRAULIC TOOLS

SECTION 1

GENERAL

INTRODUCTION

1. This chapter provides a general description, operating procedures, and safety precautions of hydraulic power supply systems (HPSS) and hydraulic tools used with the following power sources:

a. HP-1 portable power unit;

b. the field engineer section truck, MLVW SEV;

c. the field engineer section M113A2 APC;

d. the Trailer Mounted Hydraulic Tool System (TMHTS); and

e. the hydraulic auger (M113 A2 APC and MLVW SEV).

More specific operating instructions are included in the operator manual.

2. For details on trouble shooting procedures for power systems and hydraulic tools, refer to the references in Annex A to Chapter 1.

3. Hydraulic tools possess a number of advantages over hand, pneumatic and electric tools:

a. they can be operated underwater with little or no power loss;

b. greater power to weight ratio;

c. low noise level; and

d. constant and automatic oil lubrication.

4. Some disadvantages of hydraulic tools are:

a. the area of operation from the power source is limited to the length of hose which is limited to 15 m; and

b. if the tools are run off a prime mover (MLVW SEV or M113 A2 APC), it must be serviceable to ensure operation of the hydraulic power supply.

DESCRIPTION

5. A hydraulic power system generates, transmits and controls the application of power by using pressurized fluid within an enclosed circuit. The hydraulic system and the main components are:

a. **Generating Fluid Power**. The hydraulic system pumps fluid from a reservoir via a hydraulic pump to raise the pressure and flow to levels where useful work can be done;

b. **Transmitting Fluid Power**. The hydraulic flow is transmitted throughout the system using pipes, hoses, tubes and couplings. Various control valves are used to direct the hydraulic flow to where it will be used;

c. **Converting to Mechanical Energy**. The hydraulic flow is converted to mechanical energy by a hydraulic motor or piston to produce a rotary (chainsaw) or reciprocating (breaker) motion; and

d. **Conditioning the Fluid**. It is important to regulate the temperature and cleanliness of the hydraulic fluid. When the fluid is too hot, it is automatically diverted to a radiator (cooler) where it is cooled. Filters and strainers are used to remove contaminants. Water can be harmful to hydraulic fluid and must be drained periodically through a cock valve. If couplings are not tight or seals are damaged, air can enter and contaminate the hydraulic fluid.

6. There are two ways of controlling the power produced by a hydraulic system. These are called OPEN CENTRE and CLOSED CENTRE after the type of control valves used to actuate the tool being powered by the system. In open centre systems, the flow is controlled and the pressure is varied resulting in a system that operates at full flow, and low pressure when in the neutral position. For closed centre systems, the flow is varied, the pressure is controlled, and the system operates at no flow and high pressure in the neutral position.

7. The HP-1 portable power unit and the hydraulic systems found on the M113 A2 APC, MLVW SEV and the TMHTS are open centre systems. The hydraulic tools can operate either on open or close centre systems. All four hydraulic power systems are similar, in that:

a. 14 kPa pressure is developed;

b. hydraulic flow range for the hydraulic tools is 22 to 35 litres per minute (lpm). If the flow rate is less than 22 lpm, tool performance will drop off. At rates above 35 lpm, the tools could be damaged by overheating; and

c. the hydraulic oil temperature is not to exceed 60°C.

GENERAL SAFETY PRECAUTIONS

8. The following safety precautions are common to all hydraulic power supply systems and tools:

a. before cutting, digging, or drilling, check for underground cables and utility lines, especially in urban areas

b. wear protective clothing, eye and hearing protection for the type of tool being operated and do not wear clothing that could get caught in rotating parts;

c. do not expose hydraulic fluid to open flame;

d. check the hoses, fasteners and fittings for damage and tightness before starting the tools. Do not over tighten hydraulic fittings;

e. escaping hydraulic fluid can cause personal injury. Correct leaks as they occur and do not use hoses which show signs of bulging or damage. Ensure that lines, hoses, etc, are not under pressure before attempting repair or removal;

f. ensure the hoses are to the rear of the operator;

g. never use tools around energized power lines;

h. when the hydraulic lines become too hot to hold with bare hands do not operate the unit. In the event of a burst hose, fluid hotter than 60^{o} can cause severe burns;

j. flow direction must be maintained from the male to the female coupling;

k. do not lay the tool hose where it could be damaged by traffic;

m. clean up oil spills immediately;

n. do not attempt to locate hydraulic leaks by feeling around hoses and fittings with bare hands. Pin hole leaks can penetrate the skin. To inspect for leaks, turn off the unit, clean it, run it for a moment, shut it down and then inspect;

p. do not operate the unit until a power tool has been connected to a hydraulic hose;

q. connect return hoses first and disconnect them last to avoid trapped pressure within the tool;

r. when the hoses are not attached to tools, the free ends of the hoses should be attached together. This will avoid pressure developing in the hoses due to exposure to the sun; and

s. clean tools using the proper degreasing solvent, regrease and dry with lint free cloth. Clean the couplings before use with a lint free cloth.

SECTION 2

HYDRAULIC POWER SUPPLY SYSTEMS

AND POWER AUGER

STANLEY HP-1 PORTABLE POWER UNIT

1. The HP-1 (Fig 6-2-1) is portable and can be wheeled close to a job site using the retractable handles. The hydraulic pump operates at 30 Lpm. It is powered by a gas operated 18 horse power (hp) Briggs and Stratton engine with an electric start and 19 litre fuel tank. It weighs 100 kg and requires two personnel to operate.

Fig 6-2-1 Stanley HP-1

2. **Safety Precautions**. In addition to the general safety precautions for all hydrualic systems, the following safety procedures shall be adhered to before, during and after operation:

a. do not smoke while refuelling;

b. wipe up fuel spills immediately;

c. do not leave the hydraulic pump unattended; and

d. do not operate the unit until a power tool has been connected to a hydraulic hose.

3. **Pre-start**. The following pre-start checks shall be made:

a. check the engine and hydraulic oil levels;

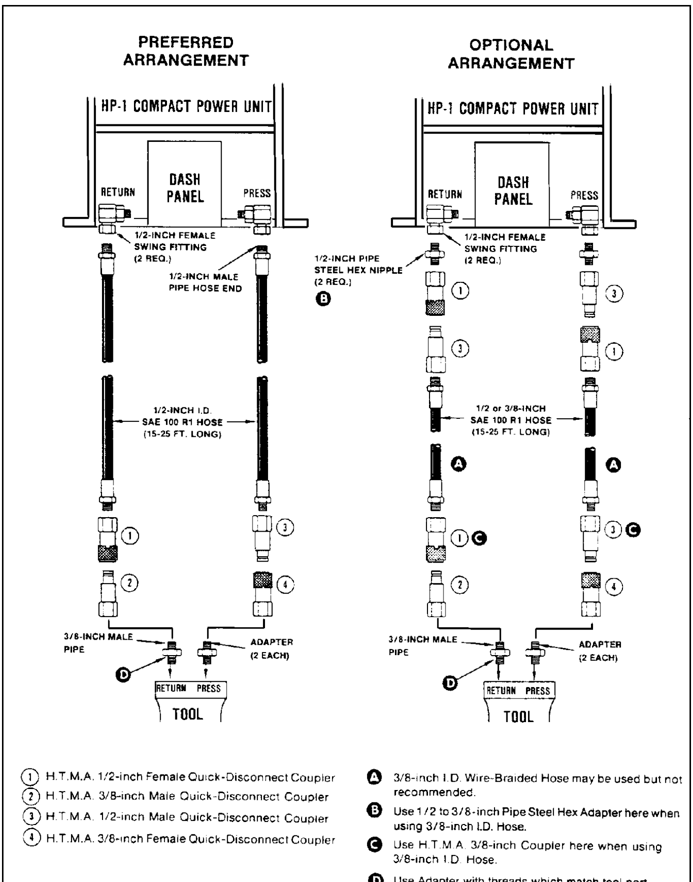


Fig 6-2-2 Hydraulic Connections

b. check the fuel level;

c. check for cracks, loose bolts or screws;

d. check battery level and terminals;

e. check hoses and connections for damage; and

f. connect the tool to the power unit (Fig 6-2-2).

4. **Start-up**.

a. release the "**HOLD 30 LPM CONTROL LINK**" (located on the Speed Control Actuator)to allow the automatic throttle to control the engine speed during start-up (Fig 6-2-3). **Important:** Failure to release the" **HOLD 30 LPM CONTROL LINK**" during start-up causes the engine to speed up too quickly before warming. This damages the engine and the hydraulic pump;

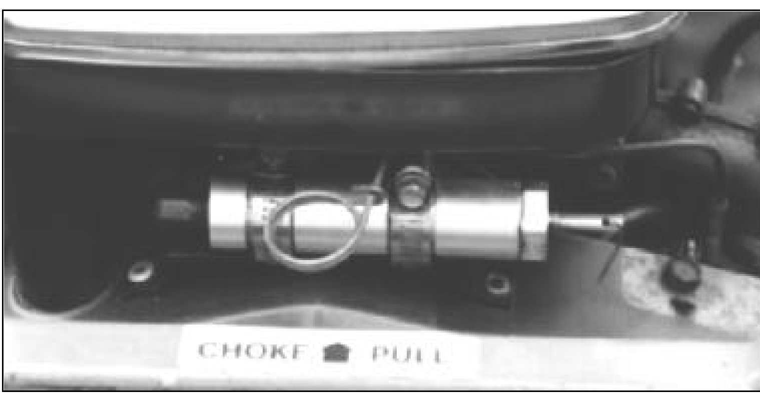


Fig 6-2-3 Speed Control Actuator Cylinder Adjustment

b. move the control lever to **TOOL OFF** (Fig 6-2-4);

c. set the **ENGINE** switch to **ON**;

d. move the control lever to **START.** Engage the choke if necessary by pulling it out;

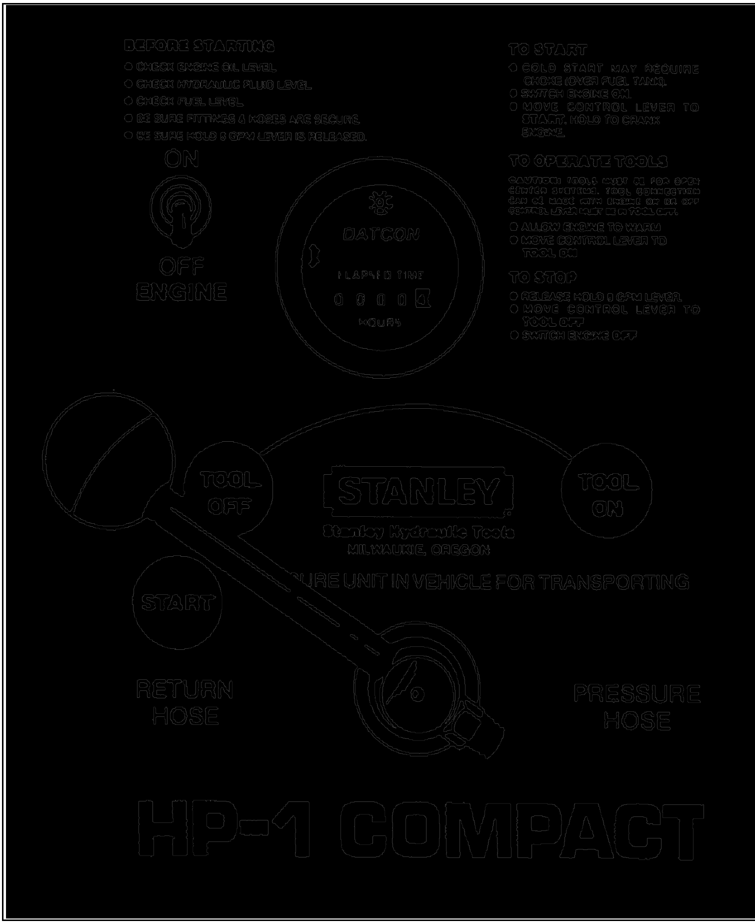


Fig 6-2-4 HP-1 Operating Controls

e. allow the engine to warm with the choke in;

f. without the choke, move the control lever to **TOOL ON**; and

g. when the tool trigger is pressed or released the automatic throttle will increase or decrease the engine speed.

5. **Stopping**.

a. release the "**HOLD 30 LPM CONTROL LINK**". **Important:** Failure to so, can cause the exhaust system to load with gasoline and backfire;

b. move the control lever to **TOOL OFF**; and

c. set the **ENGINE** switch to **OFF.**

6. **Maintenance**.

a. check and fill fuel;

b. inspect all hoses and keep all couplings clean;

c. replace oil filters on a regular basis;

d. clean air filters every 5 hours or more frequent when working conditions require; and

e. use the proper hydraulic fluid. ie: Chevron AW-MV-32.

7. **Emergency Procedure.** In the event of an equipment emergency such as an out-of-control tool or hydraulic leak, move the control lever to **TOOL OFF** and shut down the hydraulics by switching the engine off.

8. **Cold Weather Operation**. Run the engine at low speed with the control lever on **TOOL OFF** long enough to bring the hydraulic fluid temperature up to 50°C. or until the top of the hydraulic filter feels warm.

HYDRAULIC AUGER

9. The augers found both on the M113 A2 APC and MLVW SEV are almost identical. They differ in how the controls are mounted, the hydraulic power generation and in that the MLVW SEV must deploy stabilizers before augering. The auger is composed of the following major components:

a. **Auger Feed Motor**. The feed motor is located near the top of the auger mast and powers a chain drive system that raises or lowers the drill head;

b. **Rotational Drive Motor**. The rotation motor is located on the drill head. It powers the auger flight and auger head;

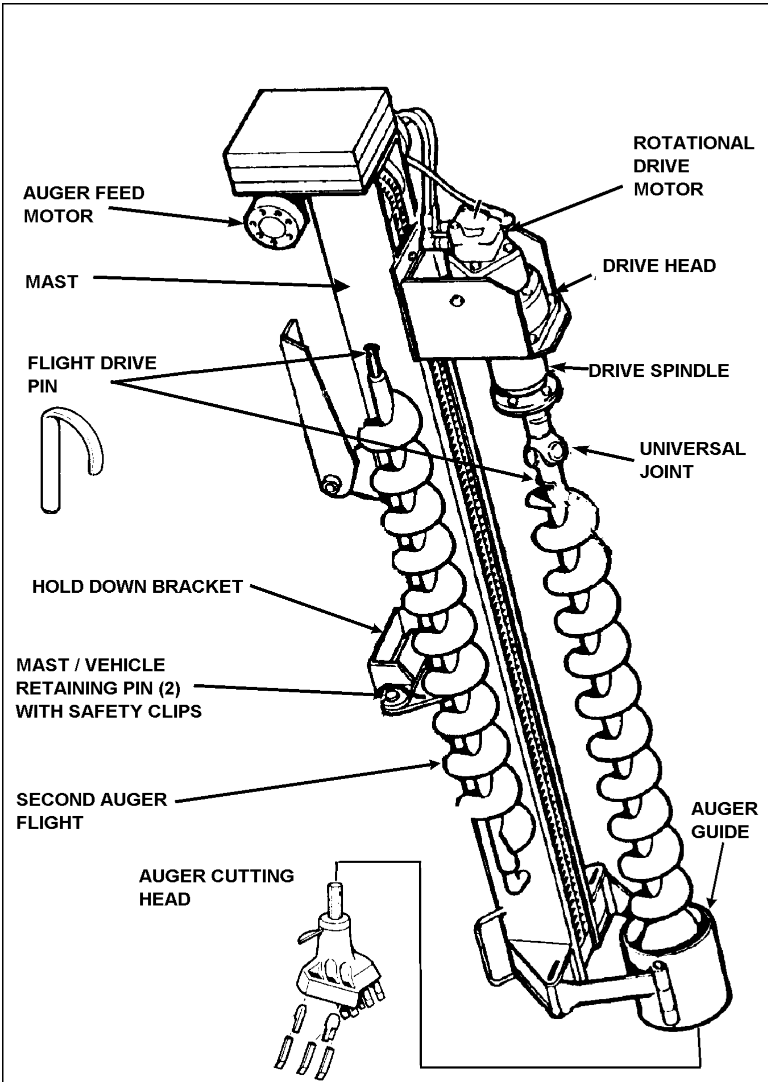


Fig 6-2-5 Hydraulic Auger

c. **Mast**. The mast supports the drill head, auger flight and auger cutting head;

d. **Auger Flight**. The auger flight is connected to the drill head by a universal joint so that the flight can be easily removed or installed;

e. **Auger Cutting Head**. The cutting head holds ten (10) cutting teeth and is attached to the lower end of the bottom most flight; and

f. **Auger Guide**. The auger guide is located at the base of the mast and supports the cutting head and flight when starting a drilling operation.

10. Refer to the operator manual to add an extension, change an auger flight, or to repair the cutting heads.

HYDRAULIC AUGER SAFETY PRECAUTIONS

11. The following safety precautions apply to the power auger:

a. two personnel are required to operate the auger;

b. maintain a 3 m distance between the auger and overhead power lines;
c. check for overhead obstructions such as power lines and tree limbs before raising the mast;

d. turn off the motor before oiling, greasing or adjusting any moving parts. Replace all guard panels before restarting the auger; and

e. use a shovel to clear soil from the rotating auger, never use hands or feet.

M113 A2 HYDRAULIC TOOLS AND AUGER

12. **Hydraulic tools**. The location of the hydraulic controls on the M113 A2 APC are shown on the next two pages. The procedures for operating hydraulic tools from the M113 A2 APC are:

a. place the vehicle within 15 metres of the work area so the hydraulic hoses can reach the site;

b. engine speed must be at 650 rpm (idle) and never exceed 2500 rpm during tool operation;

c. pull out the hose from the hose reel to the required length, ensuring the hose reel ratchet is engaged to prevent the hose from rewinding;

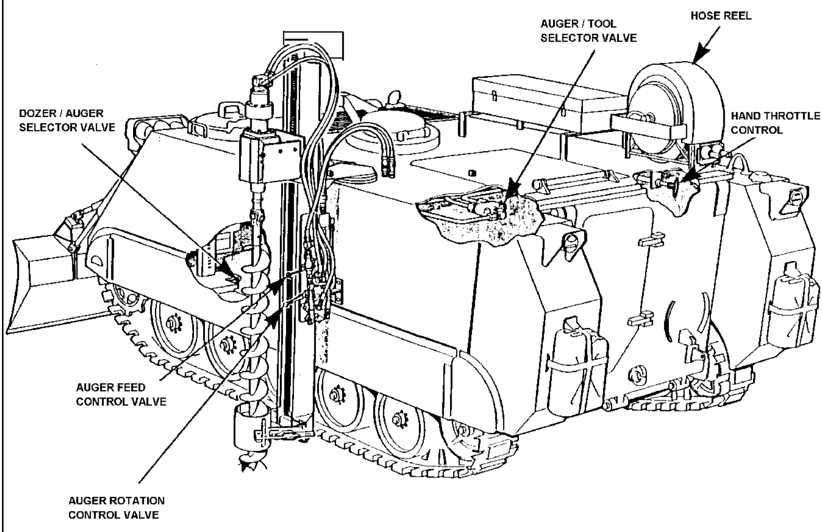


Fig 6-2-6 Location of M113 A2 APC Hydraulic Control Valves

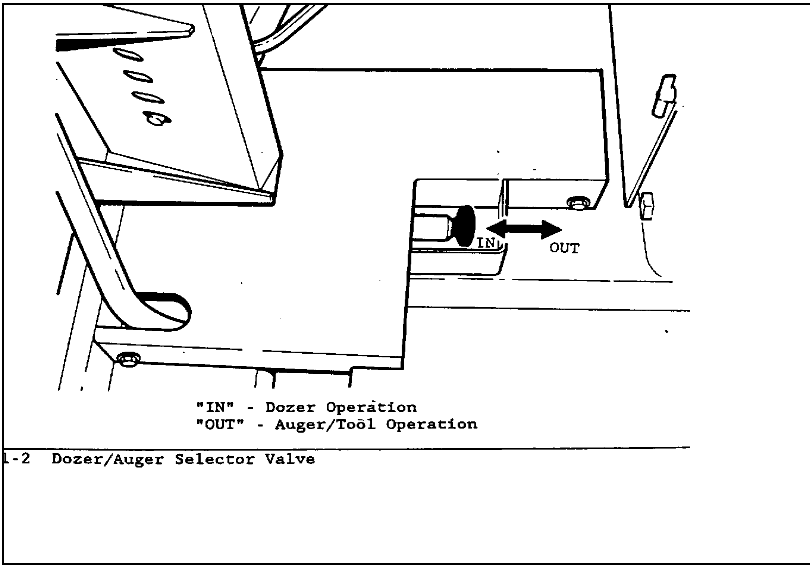


Fig 6-2-7 The Dozer/Auger Selector Valve

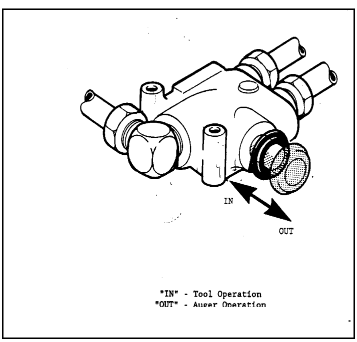


Fig 6-2-8 Auger/Tool Selector Valve

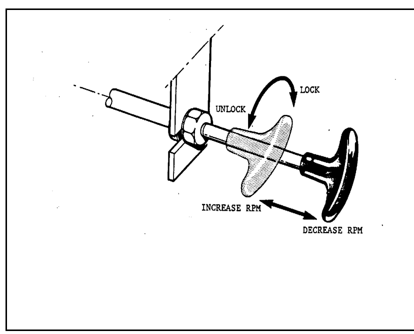


Fig 6-2-9 Remote Hand Throttle Control

d. before connecting a tool, pull the auger/tool selector valve out to the **AUGER OPERATION** position. Pull the dozer/auger selector valve out to the **AUGER** position;

e. after cleaning the quick disconnect couplings on the hose and on the tool, connect the tool to the hose;

f. push the auger/tool selector valve in to the **TOOL** position;

g. before disconnecting, pull the auger/tool selector valve to the **AUGER OPERATION** position;

h. disconnect the tool and connect the hose connectors to each other; and

j. pull slightly on the hose to disengage the hose reel ratchet and allow the hose to rewind under control.

13. **Hydraulic Auger**. To operate the auger, the auger mast must first be unstowed and positionned as follows:

a. lock the tracks by pulling back and locking the steering levers;

b. ensure the dozer/auger selector valve is in the **DOZER** position (out) (Fig 6-2-7);

c. check that the auger rotation and feed controls (Fig 6-2-13) are in **NEUTRAL**;

d. release the mast from the hold down bracket;

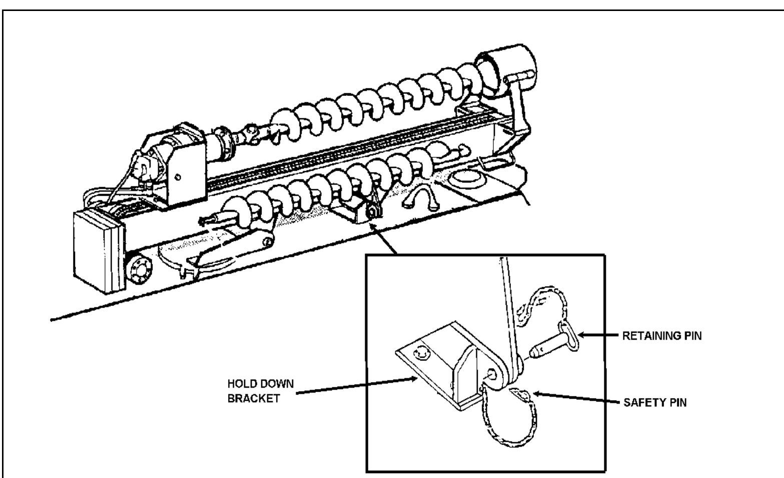


Fig 6-2-10 Release Mast from Hold Down Bracket

(1) pull the safety clips from the retaining pins (Fig 6-2-7), and

(2) remove the retaining pins out of the hold down bracket;

e. working from the rear, lift the bottom end of the mast by its handles. **Danger:** The mast is heavy and requires two people to move it;

f. under control, swivel the bottom end of the mast 90 degrees out to the side then down, in line with the side bracket;

g. insert the two retaining pins to secure the mast (Fig 6-2-11); and

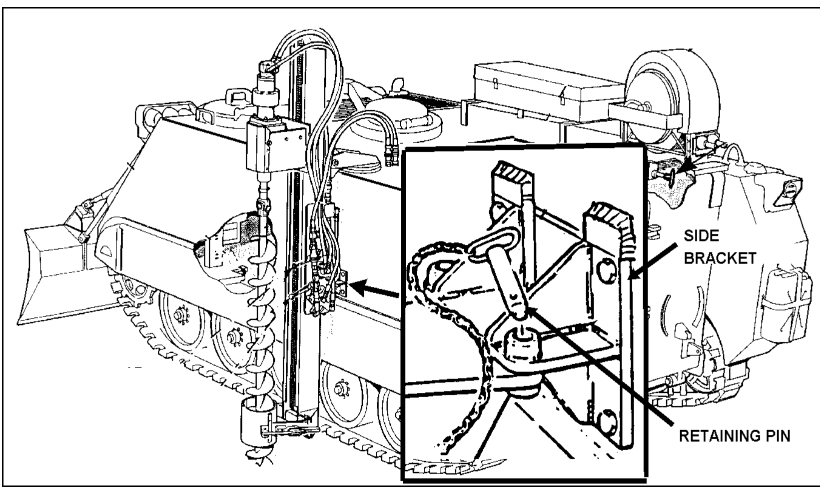


Fig 6-2-11 Securing Auger Mast to Side Bracket

h. lock the turntable in place (Fig 6-2-12) by unfastening the locking pawl tie down strap and flipping the locking pawl into the turntable slot.

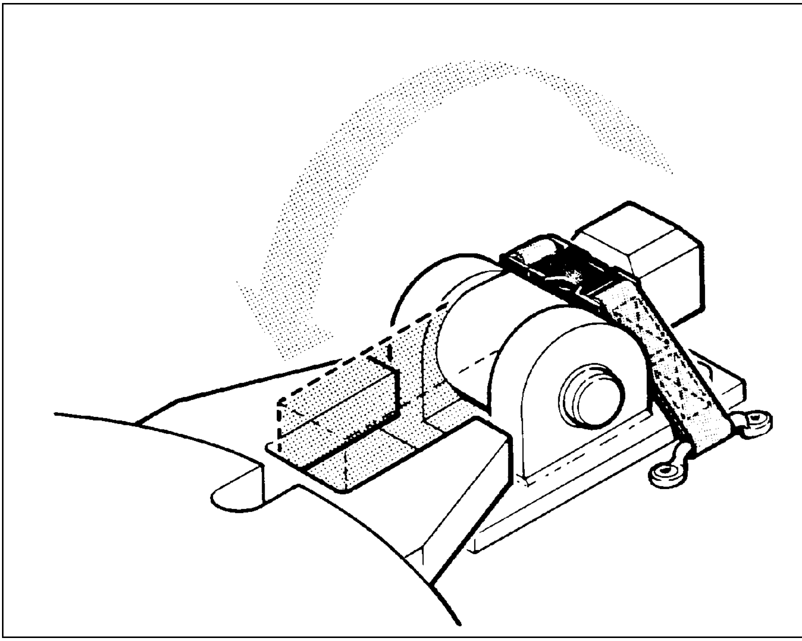


Fig 6-2-12 Turntable Locking Paw

14. Operating the auger:

    a. first ensure the auger flight hangs freely in the guide, in line with the drive sopindle and with the mast. Alignement is important to permit subsequent auger flights to be added without difficulty;

    b. change the auger/tool selector valve (Fig 6-2-13) to the auger position (out);

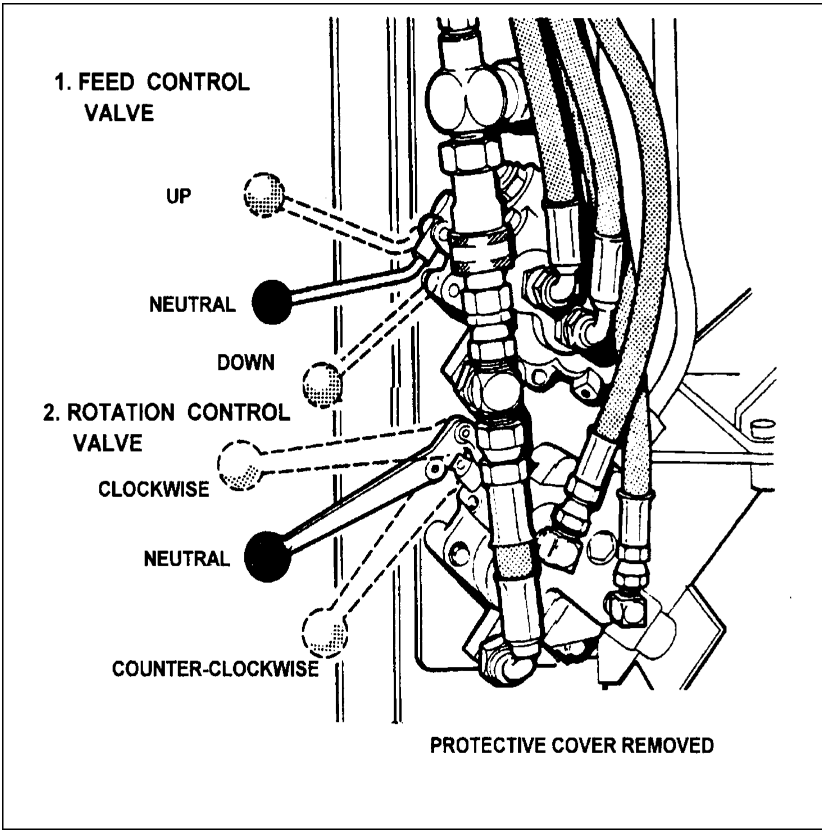


Fig 6-2-13 M113a APC Hydraulic Control Levers and Functions

c. ensure the flight assembly hangs free in the auger guide, and the auger guide is latched;

d. ensure the drive spindle, universal joint and flight assembly are not obstructed and can rotate freely;

e. lower the cutting head to the ground surface by moving the feed control valve lever down, then return it to the neutral (centre) position (Fig 6-2-13);

f. adjust auger rotation speed to between 1500 and 2250 rpm by:

(1) unlocking the remote hand throttle control (Fig 6-2-9) by turning it counterclockwise,
(2) pushing the handle in slowly to increase the speed to the proper rpm as seen on the tachometer, and
(3) locking the handle by turning it clockwise;

g. start rotation of the auger by pushing the auger rotation control feed lever down;

h. with the auger rotating, slowly push the feed control valve lever down to start augering. The depth the auger will go depends on how far the feed control valve lever is pushed down; and

j. during augering, raise and lower the auger to clear it of soil and debris. The maximum hole depth without the extension is 1.5 m.

15. **Emergency Procedures.** In the event of an emergency such as an out-of-control tool or a hydraulic leak:

a. change the auger/tool selector to the opposite setting;

b. unlocik and pull out thwe remote hand throttle control to reduceRPMs, and

c. shutdown the hydraulics pump by turning off the vehicle engine.

MLVW SEV HYDRAULIC TOOLS AND AUGER

16. The hydraulic system on the MLVW SEV is composed of the following items:

a. **Hydraulic Pump**. Hydraulic power for auger operation is supplied by a tandem hydraulic pump that is unique to auger-equipped trucks. The hydraulic pump is driven by the power take-off (PTO) that is on all winch or crane equipped 2½ Ton Medium Logistics Vehicle Wheeled (MLVW) trucks;

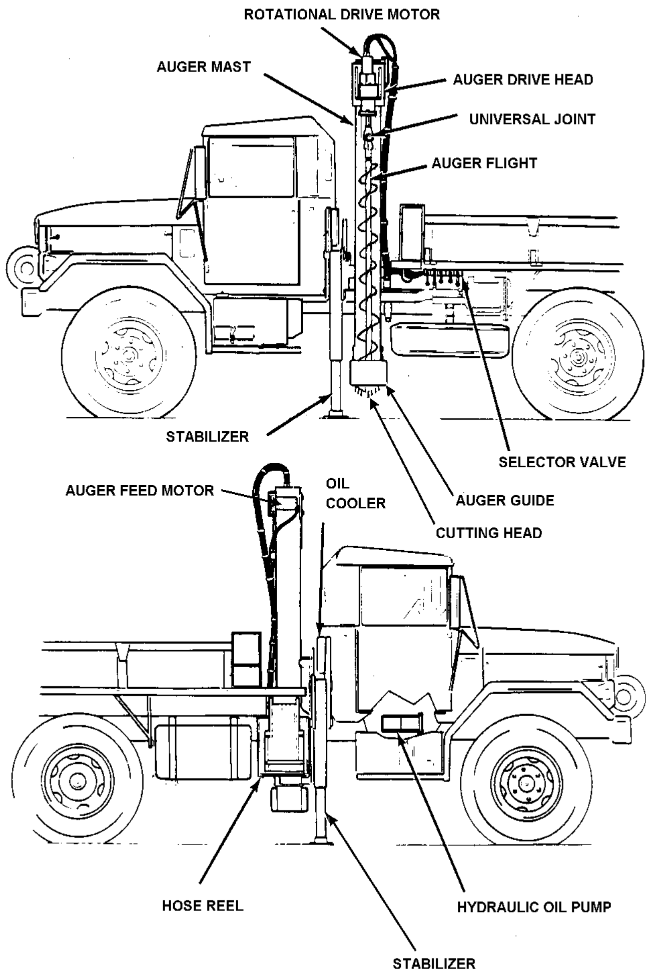


Fig 6-2-14 MLVW SEV Hydraulic System Components

b. **Selector Valve**. Hydraulic hoses carry the hydraulic oil directly from the hydraulic pump to the selector valve. The selector valve distributes the hydraulic oil to one or more of the following components, depending on which selector valve levers are activated;

(1) the hose reel,

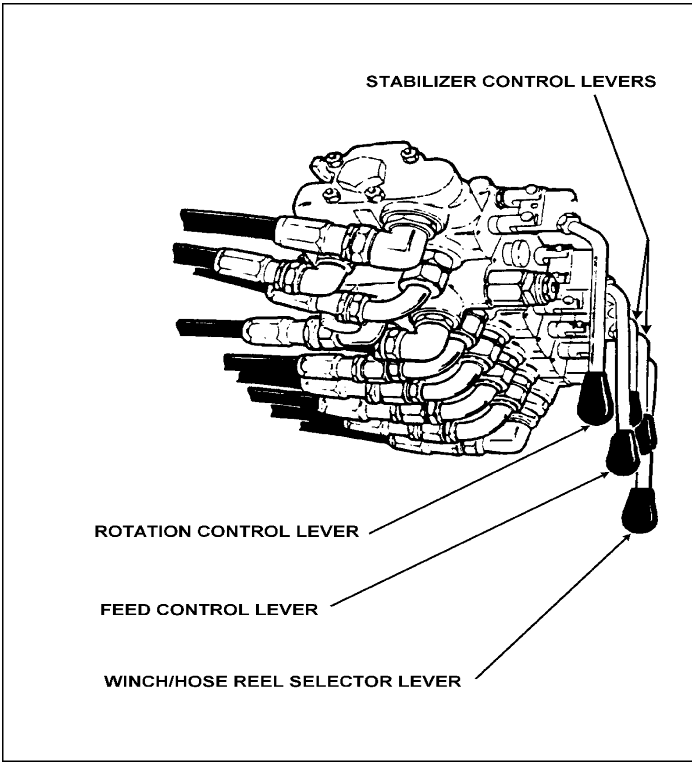


Fig 6-2-15 Selector Valve Levers

(2) the right and left stabilizers,

(3) the feed motor, and

(4) the rotation motor.

c. **Hose Reel**. The hose reel is located on the right side of the truck and provides a means to connect hydraulic tools to the hydraulic system. The hose reel contains 15 metres of hydraulic hose that is extended manually and retracted by spring tension. It automatically locks in position when the hoses have been extended to the desired length;

d. **Stabilizers**. A hydraulic stabilizer on each side of the vehicle supports it during augering operations. The stabilizers are stowed facing upward and are manually lowered into position prior to stabilizing the truck;

e. **Feed Motor**. The feed motor is located near the top of the auger mast and it powers a chain drive system that raises or lowers the drill head;

f. **Rotational Drive Motor**. This is located on the drill head. It powers the auger flight and auger cutting head;

g. **Oil Cooler**. The oil cooler is located at the rear of the vehicle cab. Hydraulic oil from all the hydraulic components flows through the oil cooler before returning to the truck hydraulic reservoir when the hydraulic oil temperature exceeds 35°C;

h. **Auger**. The auger is stowed diagonally between the cab and cargo body of the truck. All auger operations are performed at the left side of the truck. The auger mast pivots on the three point mount so it can be manually raised into the vertical position for operation; and

j. **Automatic Throttle Switch**. This switch is on the dashboard of the truck. It is used to increase the engine idle RPM to provide sufficient hydraulic power for auger or hydraulic tool operation. The switch will not increase RPM unless the transmission is in neutral.

17. **Stabilizer and Auger preparation**. To stabilize the truck for auger operation:

a. if the truck is parked across a grade on a hill, lower the stabilizer on the downhill side first, then the uphill side;

b. position the stabilizers before augering by engaging the PTO:

(1) apply the truck service brakes,

(2) start the truck engine,

(3) place the transmission range selector lever in any one of the drive ranges to stop the transmission PTO gear. To prevent damage to the PTO and transmission gears, do not attempt to engage the PTO when the transmission range selector lever is in **"N"** (neutral).

(4) pull out the PTO control knob to engage the PTO. The PTO indicator lamp will light when the PTO is engaged. If the PTO knob does not come out to its fully engaged position, push the PTO control knob in and ease off the service brakes enough to allow the truck to move slightly. Apply the service brakes and pull out the PTO control knob to the fully engaged position,

(5) place the transmission range selector in **N** (neutral),

(6) apply the hand brake and temporary electric park brake, and

(7) move the automatic throttle switch to **ON**

c. warn nearby personnel to stay clear of the stabilizer before extending it, remove the stabilizer pin, and swing the stabilizer downward into position. Secure the stabilizer with the stabilizer pin and safety pin and chain (Fig 6-2-16);

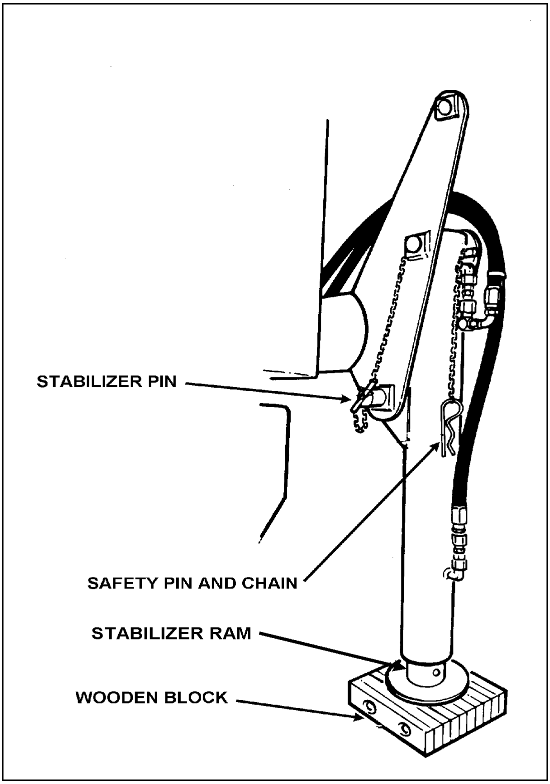


Fig 6-2-16 Positioning The Stabilizer

d. move the automatic throttle switch to **ON;**

e. ensure the winch/hose reel selector lever is centred and extend the ram so that it bears solidly on the ground. **Important:** Do not hold the control lever open after the ram reaches the end of its travel, and do not lift or level the truck with the stabilizer ram, and

f. position the opposite stabilizer in the same manner as already described. When on soft ground or if the rams do not reach the ground, use wooden blocks.

18. Ensure the auger mast and area overhead is free of obstructions and unstow the auger mast as follows:

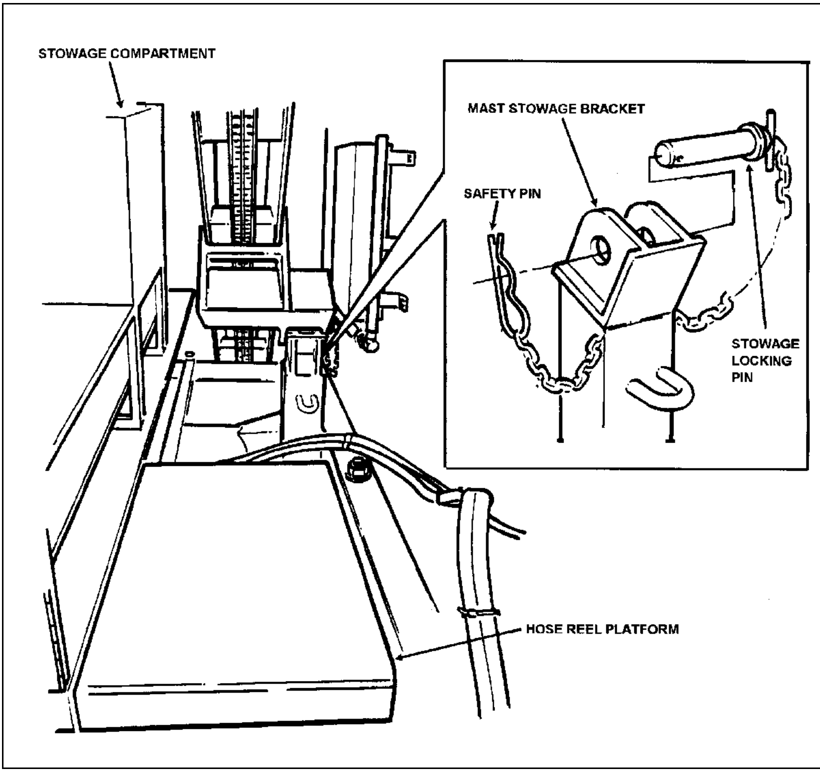


Fig 6-2-17 Mast Stowage Bracket and Stowage Pin

a. remove the safety pin from the stowage locking pin and withdraw the stowage locking pin from the mast stowage bracket, Do not insert the stowage locking pin into the mast stowage bracket while it is in the vertical operating position. Ensure it remains in the pin holder when the mast is vertical;

b. standing above the hose reel, lift the mast free of the mast stowage bracket and swing it into a vertical operating position; and

c. remove the mast locking pin and safety pin from the pin stowage bracket and insert into the mast bore, securing with safety pin as shown in Fig 6-2-18.

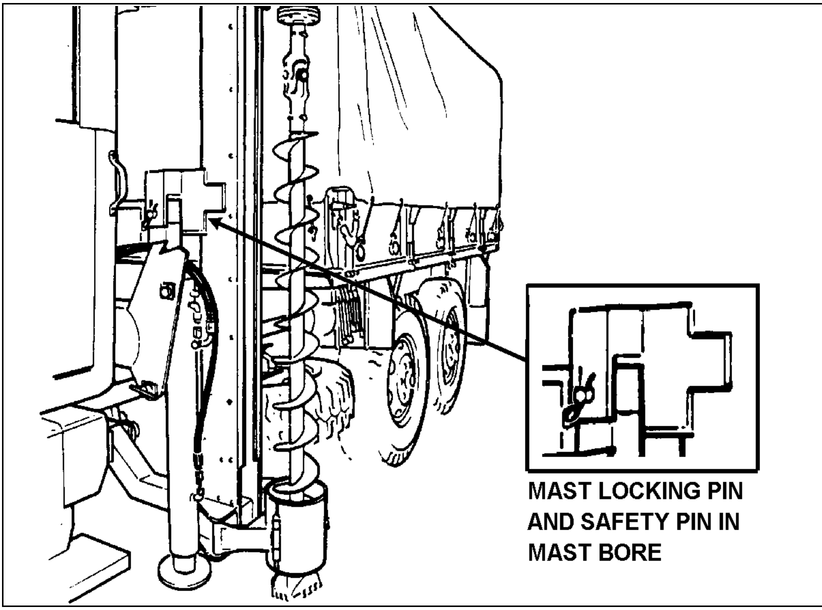


Fig 6-2-18 Mast Bore and Mast Locking Pin

19. To operate the auger:

   a. ensure the winch/hose reel selector lever is centred (Fig 6-2-15);

   b. ensure the flight assembly hangs free in the auger guide and auger guide is latched;

   c. lower cutting head to the ground surface by pushing the feed lever inward, then releasing it to neutral (centre) position. The speed increases as the lever is pushed down;

   d. start clockwise rotation of the flight assembly by pushing the **rotation control lever** inward; and

   e. during augering, raise and lower the flight to clear it and the hole of soil and debris.

20. **Hydraulic Tools**. To use the other hydraulic tools, position the vehicle far enough from the job site so as not to interfere with the tool operation but close enough to perform the work without having to move the truck. The hose reel permits the hydraulic tool to be used within 15 m from the truck.

21. To enage the PTO:

a. apply the truck service brakes;

b. start the truck engine; **Important:** To prevent damage to the PTO and transmission gears, do not attempt to engage the PTO when the transmission range selector lever is in **N**;

c. place the transmission range selector lever in any one of the drive ranges to stop the transmission PTO gear;

d. pull the PTO control knob out to engage it. The PTO indicator lamp will light when it is engaged. If the PTO knob does not come out to its fully engaged position, push the PTO control in and ease off the service brakes enough to allow the truck to move slightly. Apply the service brakes and pull out the PTO control knob to the fully engaged position;

e. place the transmission range selector in **N** (neutral);

f. apply the hand brake and temporary electric park brake; and

g. move the automatic throttle switch to **ON**.

22. Connect a hydraulic tool to the hose reel (Fig 6-2-19) as follows:

a. disconnect the two hose reel quick disconnect fittings from the hose keeper;

b. cover the hose keeper connectors to prevent hydraulic oil contamination;

c. clean the hydraulic tool fittings and connect the hose reel quick disconnect fittings to the hydraulic too. **Important:** Quick disconnect fittings must be cleaned carefully before connecting hydraulic tool. Contaminated hydraulic oil will destroy the hydraulic tool and components of the hydraulic system;

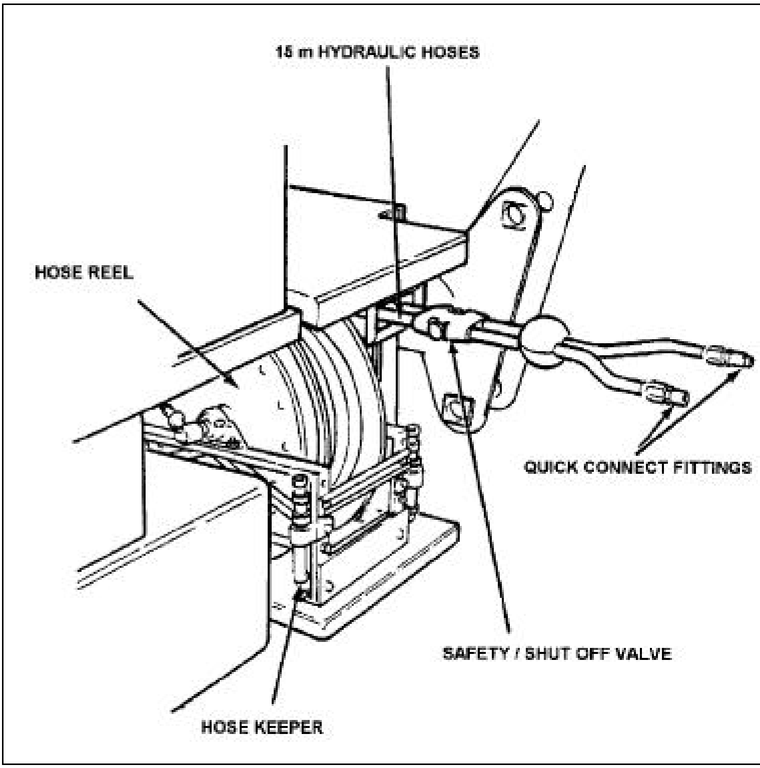


Fig 6-2-19 Hose Reel Components

d. move the winch/hose reel selector lever inwards to the hose reel position; and

e. move the safety/shutoff valve control to the **TOOL ON** position. The hydraulic tool is now ready for operation.

23. To change hydraulic tools:

a. move the safety/shutoff valve control to the **TOOL OFF** position;

b. disconnect the hose quick disconnect fittings from the hydraulic tool;

c. stow the removed tool in the tool box;

d. clean the fittings on the new tool and connect the hose quick disconnect fittings to the tool; and

e. move the safety/shutoff valve control to **TOOL ON**. The hydraulic tool is now ready for operation.

24. Disconnect and stow a hydraulic tool as follows:

a. move the safety/shutoff valve control to **TOOL OFF**;

b. move the winch/hose reel selector lever to the **CENTRE** position;

c. disconnect the hose reel quick disconnect fittings from the hydraulic tool;

d. clean the fittings on the hose keeper and connect the hose reel quick disconnect fittings to the hose keeper;

e. rotate the hose reel until all slack is removed from the hydraulic hoses;

f. clean and stow the hydraulic tool in the hydraulic tool box;

g. move the automatic throttle switch to the **OFF** position to return the engine to idle RPM (700 RPM); and

h. disengage the PTO after hydraulic tool operation as follows:

(1) place the transmission range selector in any one of the drive ranges to stop the transmission PTO gear,

(2) push the PTO control knob fully in. The PTO lamp will then go out,

(3) place the transmission range selector in **N** (neutral) and if required, stop the truck engine, and

(4) de-activate the temporary electric park brake.

25. **Emergency Procedures**. If an emergency such as an out-of-control hydraulic tool or a leak occurs;

a. **Out-of-Control Tool.** If necessary let the tool fall, and shut off the in-line tool on/off valve (on the hydraulic hose near the tool end); and

b. **Leak**. Disengage the PTO and do not operate the auger or hydraulic tools until a repair is completed. **Danger:** Escaping hydraulic oil under pressure can cause personal injury. Do not attempt to tighten couplings with a wrench.

COLD WEATHER OPERATION

26. **Hydraulic Tools and PTO**. Cold weather operations require particular attention. To prevent damage, cold and wet hydraulic tools should be warmed using a personal heater or by placing the tool near the engine exhaust. Cold weather operating procedures are as follows;

a. start the truck engine, engage the PTO with the engine on low idle for 15 minutes before switching on the automatic throttle switch. After ensuring the hose reel quick disconnect fittings are attached to the hose keeper, push the winch/hose reel selector lever inward. This will circulate the hydraulic oil through the system and warm the system to operating temperature (32°C);

b. ensure the safety shutoff valve is set to **TOOL OFF**, before connecting the hydraulic tool to the hoses (Fig 6-2-4);

c. connect the tool to the hose reel quick disconnect fittings and set the safety shutoff valve to **TOOL ON**; and

d. before starting the task, slowly operate the tool until it feels warm to the touch.

27. **Hydraulic Auger**. When the temperature falls below 0^{o} C, the hydraulic auger and fluid should be warmed before using the following procedure:

a. connect the two free ends of the hose reels together;

b. check that the auger rotation and feed controls are in **NEUTRAL**;

c. pull the auger/tool selector valve to the out position **(AUGER OPERATION);**

d. let fluid circulate through the system for five minutes until the fluid warms to **38^{o} C** and tool hoses feel warm to the touch;

e. push the auger/tool selector valve to the **TOOL** position; and

f. pull the auger feed lever to the **RAISE** position. Release the feed lever when the auger hoses feel warm to the touch.

EXTREME HOT WEATHER

28. To prevent damage to the hydraulic system and tools, the hydraulic oil temperature is not to exceed **$60\ ^{O}$C** and the tools and hoses are not to become **very hot** to the touch. The procedures for hydraulique operation in extremely hot weather are as follows:

a. if practical, park the vehicle in a shaded location;

b. operate the hydraulique tool in the normal manner. The tool will be too hot to handle once the maximum temperature is exceeded; and

c. to reduce the hydraulique tool temperature, cease operation and allow the hydraulique oil to recirculate until the temperature is reduced to 32^0 to 54^0C.

SECTION 3

TRAILER MOUNTED HYDRAULIC

TOOL SYSTEM (TMHTS)

GENERAL

1. The 3.5 ton Trailer Mounted Hydraulic Tool System (TMHTS) is designed to provide military engineers with the capability of using both hydraulic and air driven tools. The TMHTS consists of a 3.5 ton M353 trailer chassis and a hydraulic tool trailer adapter kit. It is towed by a Heavy Logistic Vehicle Wheeled (HLVW). It is capable of travelling cross-country at a maximum speed of 40 KPH and 80 kph for highway conditions.

Fig 6-3-1 Trailer Mounted Hydraulic Tool System – Open Configuration

2. The TMHTS consists of a hydraulic power unit with three integral hydraulic circuits (systems) which permits simultaneous operation of three hydraulic power tools. One integral circuit can operate a self contained, chassis mounted air compressor. A variety of hydraulic tools with ancillary

equipment are included: CO23 Cutoff Saw, IW12 Impact Wrench, CS06 Chainsaw, HG60 Grinder, BR45 and BR67 Breakers, HD45 Hammer Drill with two drill extensions, two SK58 Sinker Drills and a water pump.

3. Additional equipment includes a portable hydraulic power unit (HP-1), an exothermic arcair slice cutting torch, two water hoses (one for suction and one for supply), and a set of inflatable lifting bags (Powermats).

TMHTS SAFETY PRECAUTIONS

4. The TMHTS safety precautions and procedures are:

  a. use the stabilizers and castor wheels when operating the system;

  b. deploy boards or load spreaders under the rear stabilizers and castor wheels to maintain the system on a level plane when operating on soft or uneven ground. Do not overload the stabilizers since the rear stabilizers are only designed to provide stability to the trailer and not take its full weight;

  c. ensure all door props are secured in place using the brackets and locking pins before working beneath them; and

  d. keep all camouflage netting clear of moving parts and exhaust systems when the TMHTS is in operation.

DESCRIPTION

5. The Hydraulic Trailer adapter kit is designed so all systems can be accessed or operated from outside of the trailer by opening the side, rear, and front door assemblies. The components of the TMHTS are:

  a. **Control Panel**. The control panel controls the hydraulic and air compressor systems. Instrumentation includes oil temperature and engine temperature gauges. A 24 volt DC system governs the system operation.

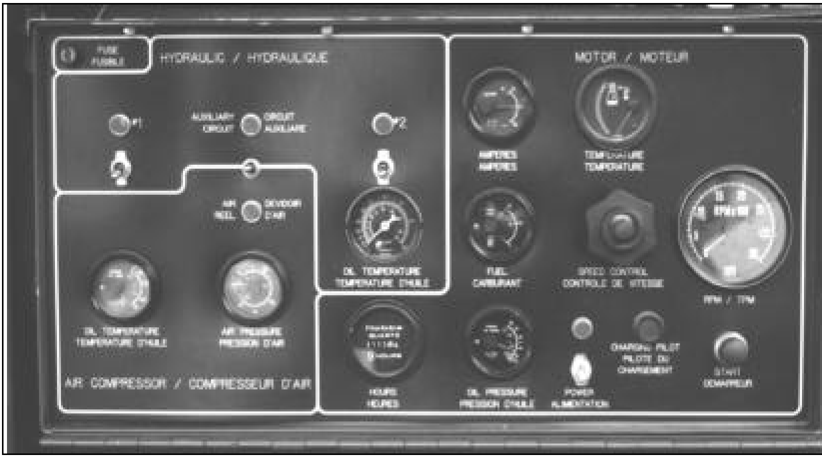


Fig 6-3-2   TMHTS Control Panel

b. **Battery Box Compartment**. The battery box compartment houses two 12 volt batteries, configured into 24 volts, used for starting the hydraulic system. A slave receptacle is located at the front of the trailer which is wired through to the compartment wall to the batteries.

c. **Storage Cabinet**. A three drawer storage cabinet provides security for tools, repair parts and hardware. There is also two trays which can be removed from their position by releasing spring pins, lifting the trays and pulling out. Tools are secured by tie down straps.

d. **Hydraulic Tool Storage Trays**. The TMHTS includes storage trays for the hydraulic tools and accessories. These tools are secured in the trays by brackets and spring pins or straps and fasteners.

e. **Auxiliary Hydraulic Circuit Hookup**. This hookup has quick disconnect fittings for supply and return lines. It provides an additional capability to operate hydraulic tools exclusive of the hose reels.

f. **Lighting**. Both red and white 24 volt DC light systems are incorporated in the trailer interior and is controlled by a switch secured to left rear roof support. Two SMP taillight assemblies are recessed into the rear door.

g. **HP 1 Hydraulic Stowage Tray**. This tray houses the HP 1 Compact system. An Al 35 generator control is located in the rear of the tray. The tray is mounted on wheels and guiderails for easy movement and access.

h. **Four Inch Service Vice**. A four inch service vice is mounted on the tailgate.

j. **Hose Reels**. There are two hose reels which permit the use the of the hydraulic power tools up to 33 m from the trailer. Hose reel #1 is located on the right side, and hose reel #2 on the left side.

k. **Fire Extinguisher**. A 9 kg dry chemical fire extinguisher is mounted directly beside the air hose reel and readily available for fighting small fires.

m. **Air Hose Reel**. A 62 m air hose is reel mounted for easy access and use. The air hose provides the capability to operate air driven tools and equipment.

n. **Arcair Slice Cutting Compartment**. The compartment provides secure storage for one complete cutting system and two spare propane cylinders.

p. **Dewatering Pumps**. A hydraulic driven dewatering pump provides the operator the capability to supply or drain water in remote locations.

q. **Hydraulic Oil Cooling System**. A hydraulic oil cooling system cools the hydraulic oil during the operation of hydraulic tools. It features an air cooling radiator with four thermostatically controlled cooling fans.

r. **HP 3 Hydraulic Power System**. The HP 3 hydraulic power system is mounted at the front of the trailer consisting of a Deutz diesel engine, hydraulic pump, hydraulic tank and a distribution/return system. The engine and pump are roller skid mounted for maintenance accessibility.

s. **Roof**. The roof ladder is mounted on the front door to permit saccess to the trailer roof to secure camouflage netting. A grab handle is located on the roof. Two roof guard rails are mounted on the trailer roof to prevent personnel from slipping off.

t. **Air Compressor**. An air compressor is mounted on the right side of the trailer front. The compressor operates from the hydraulic system controlled by a separate circuit on the control panel. It provides air to operate a variety of power tools and the inflatable air bags (Powermats). Four medium and two small air bag kits are included with the trailer.

u. **Engine Exhaust**. An engine exhaust system provides the means for exhaust fumes to exit the trailer interior. The main exhaust port is located on the trailer roof.

OPERATION

6. **Pre-operation Check**. Before operating the hydraulic system, check the following:

a. ensure all doors, except the air slice and battery compartments, are open and secured. Also, ensure that the main battery power is connected and that the diesel fuel and hydraulic oil reservoirs are filled.;

b. release the engine track securing bracket and engine hold down clamps;

c. pull out engine on its tray and secure with spring pin;

d. check oil level and top up as required;

e. check the security of fuel and oil filters and exhaust system and correct as required;

f. check hydraulic lines and fitting for leaks and correct as necessary;

g. return engine to stowed position and secure engine and engine track; and

h. check oil level sight glass on air compressor and fill as necessary.

7. **Starting the Engine.**

a. At the control panel, ensure that all switches are in the **OFF** position. Turn on the main power and confirm the indicator light is operating.

b. Open the throttle control halfway. Press the start button until the engine starts and then release it. Note that the engine has to self-prime its fuel supply and may be difficult to start initially. To manually prime the engine, refer to the Deutz Engine Operator's Manual.

c. Once the charging light has gone off, adjust the throttle to idle at 1,000 rpm and allow the engine to warm for 10 minutes. During the warm-up, check that all engine meters and gauges are operating, and the engine exhaust is exiting through the weather cap.

8. **Circuit #1**. To operate Circuit #1:

a. disengage the reel clutch and unwind hose from the hose reel #1 on the right side of the trailer and attach the required hydraulic tool;

b. at the control panel, increase the engine rpm to the required level for operation of the particular tool;

c. on completion of work, disengage the Circuit #1 toggle switch on the control panel and confirm the indicator light goes out;

d. disconnect the tool, re-engage the toggle switch, and confirm that the pressure relief valve is functioning by listening for the engine load to cycle, then disengage the toggle switch; and

e. re-engage the reel clutch and rewind the hose by pressing the momentary start switch. If there is a problem rewinding the hose, use the handcrank.

9. **Circuit #2**. Circuit #2 is operated using the same procedure as detailed for Circuit #1 except that hose reel #2 is located on the left side of the trailer, and the Circuit #2 and Reel #2 toggle switches are used.

10. **Auxiliary Circuit**. Attach the dual hose from the HP-1 system to the quick disconnect fittings at the auxiliary hook-up on the right side of the trailer. Attach a hydraulic tool to the other end of the hose and operate the Auxiliary circuit using the same procedure as detailed for Circuit #1. When work is complete, and the circuit has been disengaged, remove the dual hose from the auxiliary hook-up.

11. **Operating the Air System**.

a. disengage the reel clutch and unwind hose from the air reel located on the left side of the trailer and attach the required air driven tool with the shut-off valve closed;

b. at the control panel, engage the toggle switch for the air reel and ensure that the indicator light is operating;

c. ensure that the hose becomes pressurized and that pressure and oil temperature gauges are functioning properly. Air pressure switch disengages when pressure reaches 125 psi;

d. open the shut-off valve on tool under control to slowly pressurize the tool. The air pressure switch engages the air compressor when the pressure drops to 80 psi;

e. operate the tool according to specific operating instructions for that tool;

f. when work is completed, disengage the air system toggle switch at the control panel. When cylinder head air pressure has vented through the solenoid valve, disable the air pressure switch and close the shut-off valve on the tool; and

g. engage air system toggle switch on the control panel. When excessive pressure is vented, disengage the switch, remove the tool, and re-engage clutch for the reel. Rewind the hose with the momentary switch for the air reel.

12. **Engine Shut Down**. To shut down the engine, turn off the main power at the control panel.

INFLATABLE AIR BAGS (POWERMATS)

13. General. The Powermat is an accessory to the TMHTS, designed to lift or hold heavy objects, usually from underwater, that can not be lifted by other means. The general specifications of the inflatable air bag system are described in the table at Fig 6-3-4.

Fig 6-3-3 Powermat

Specifications	**Powermat Model**	
	KL 30	KL 60
Maximum Lift (tonnes)	39.5	68
Size (cm)	68 X 78	95 X 95
Height Inflated (cm)	37.5	52
Height Deflated (cm)	2.5	2.5
Air Capacity (litres)	675	1450
Water Capacity (litres)	75	161
Weight (kg)	14.8	25.3

Fig 6-3-4   Powermat General Specifications

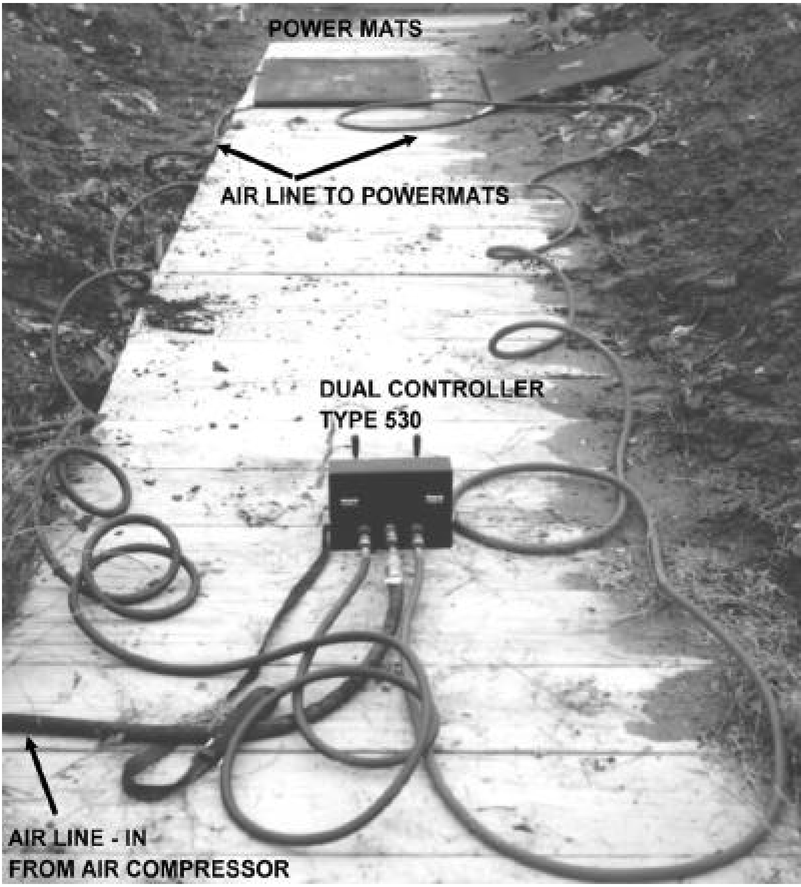


Fig 6-3-5 Powermat Components.

14. **Safety Precautions**. The following safety precautions apply:

a. ensure equipment is used only by trained personnel;

b. powermats should never be inflated without control equipment supplied;

c. do not place Powermats near hot exhaust;

d. keep clear of loads unsupported by chocks during lift operations;

e. do not use delivery hose to recover or reposition Powermats;

f. keep clear of the direction of anticipated thrust, particularly when making space with partially inserted Powermats; and

g. do not use Powermats if they are found to be leaking.

15. **Operation**. Powermats are designed to be used in conjunction with the TMHTS, however other air supply systems may be used such as scuba tanks, back pack cylinders, and foot or hand pumps. Operating guidelines are as follows:

a. assess the weight to be lifted;

b. select the size of Powermat to be used;

c. insert Powermats under the load to achieve maximum stability and surface contact;

d. connect the delivery hose to the Powermats;

e. ensure levers on all controllers are in the OFF position;

f. connect delivery hose snap-fit - red to the left and green to the right;

Fig 6-3-6   Dual Controller Type 530

g. couple the Type 530 Controller to the air supply ensuring maximum inlet pressure does not exceed 150 psi. If using cylinder supply, connect the reduced pressure hose from the regulator to the controller inlet at the centre rear of controller housing;

h. ensure the control levers are in OFF position;

j. switch on the air supply;

k. commence inflation by moving the control levers to the inflate position. When using two or more Powermats, balance the air input paying attention to controller gauges; and

m. after use, select deflate position on the control lever.

16. **Care and Maintenance**. After use, the following maintenance procedures shall be observed:

a. wash Powermats thoroughly with soapy water;

b. examine the surface area and mark any cuts and abrasions with chalk;

c. inflate the mats to 2.45 bar and allow it to stand for 10 minutes;

d. examine the marked areas paying particular attention to the inner polyaramid core;

e. if the polyaramid core is found damaged, the Powermat should not be used. If the Powermat leaks, it is <u>not</u> repairable;

f. store Powermats between 10°C and 25°C with humidity below 75%;

g. store flat, not more than five high, in a clean dust free environment and protected from sunlight; and

h. after three years of use, the Powermat must be hydraulically tested at 12 bar for 20 minutes. Ensure the issue log card is certified with the date of test and signed.

SECTION 4

HYDRAULIC TOOLS

GENERAL

1. This section outlines the safety precautions and general operating instructions for the following hydraulic tools:

   a. SM23 Hydraulic Sump Pump;

   b. CO23 Hydraulic Cutoff Wheel;

   c. CS06 Hydraulic Chainsaw;

   d. BR67 and BR45 Hydraulic Breakers;

   e. IW12 Hydraulic Impact Wrench;

   f. HD45 Hydraulic Hammer Drill;

   g. HG60 Hydraulic Grinder; and

   h. SK58 Hydraulic Sinker Drill.

2. The general specifications for these tools are contained in the table at Fig 6-4-1. For further details on maintenance of these tools, refer to the appropriate manufacturers' manual.

Specs	**Hydraulic Tool**								
	SM23	CO23	CS06	BR67	BD45	IW12	HD45	HG60	SK58
Pressure Range (kPa)	7-14	7-14	7-14	10.5 -14	10.5 -14	7-14	10.5 -14	7-14	7-14
Flow Range	57	26-34	26-34	26-34	26-34	15-45	26-34	26-34	26-34

Specs (litres/ minute)	Hydraulic Tool								
	SM23	CO23	CS06	BR67	BD45	IW12	HD45	HG60	SK58
Weight (kg)	10.9	8.6	2.8	30	20	6	20.4	5.1	30
Length (cm)	27.9	51	36	68	65	24	57	53	66
Width (cm)	29.8	30.5	23	40	35	10	35.6	22.9	46

Fig 6-4-1 General Specifications For Hydraulic Tools

SM23 HYDRAULIC SUMP PUMP

3. The SM23 Hydraulic Sump Pump is designed for high capacity pumping. It is submersible and self-priming, and can pump up to 1 cm solids. It is lightweight, powerful, and can run dry without damage.

Fig 6-4-2 Sm23 Hydraulic Sump Pump

4. **Precautions**.

a. use a line through the hole in the pump head plug to lift the pump, do not lift the pump by the hoses;

b. **Danger:** do not put any part of the body near or under the intake while the pump is operating, and

c. the pump is not designed for use with a suction pipe inlet.

5. Operating Instructions. To operate:

a. connect a hose fitted with a 2½ inch male pipe end to the pump outlet fitting and tighten;

b. lower the pump into the liquid to be pumped, and turn on the power source; and

c. check for solids ie. gravel, rocks, being pumped. Excessive solids will reduce flow and cause increased wear. This condition can be caused by:

CO23 HYDRAULIC CUTOFF SAW

6. General. The CO23 direct-drive cut-off saw is intended for accurate dimensional cutting of concrete, steel beams, railroad rails, and pipes. It features an adjustable wheel guard and interlocking triggers to prevent unintentional operation. It can be used with standard cut-off wheels or diamond blades. Guards are tapped to accept a cooling water hose.

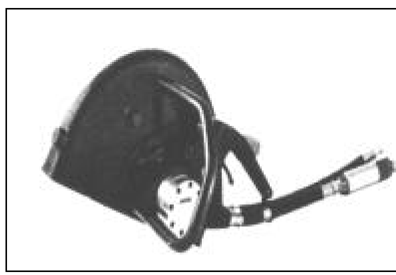


Fig 6-4-3 CO23 Hydraulic Cut-Off Saw.

7. **Precautions.** The following precautions shall be observed:

a. inspect the wheel before use;

b. when starting the saw, keep the wheel off all surfaces;

c. ensure the wheel is stopped when moving around or setting down the tool;

d. never operate without the wheel guard;

e. never store the saw with the wheel attached;

f. never cock, jam or wedge the wheel while cutting; and

g. do not use the side of the wheel as a cutting surface.

8. **Attachments**. The C023 cutoff saw includes two 35.6 cm diameter abrasive wheels, one for metal and the other for masonry.

CS06 HYDRAULIC CHAINSAW

9. **General**. The CS06 is designed with interlocking triggers, bucking spurs and hand guards. It is a versatile chainsaw, easily used for construction purposes, clearing and trimming trees and general utility use. Underwater models are also available.

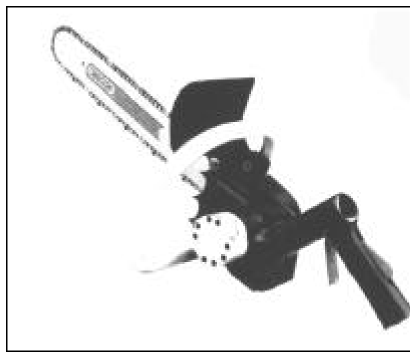


Fig 6-4-4 CS06 Hydraulic Chainsaw

10. **Precautions**. In addtion to the normal chainsaw precautions described in Chapter 4:

a. carry the chainsaw with the unit de-energized and the bar and chain to the rear;

b. make sure the power source and the operating pressure are off before inspecting the chainsaw;

c. connect the hoses to the tool hose couplers before energizing the power source;

d. stop operating the system when oil temperatures rise above 60°C; and

e. turn off the power unit or move the hydraulic control valve to N (neutral) before setting it down.

11. **Operation.** Follow the normal chainsaw operating procedures outlined in Chapter 4.

BR67 AND BR45 HYDRAULIC BREAKERS

12. **General.** The BR67 and BR45 breakers are designed for light to medium-duty operation on tasks such as concrete demolition, driving of posts, pole anchors and asphalt cutting. Both breakers feature a feathering valve to make start-up and initial placement of the steel easy. Under- water models are also available.

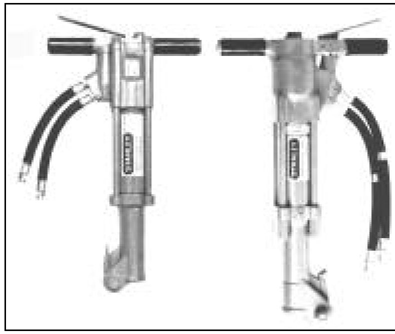


Fig 6-4-5 BR45 Hydraulic Breaker (left)
BR67 Hydraulic Breaker (right)

13. **Precautions**. Observe all safety precautions for attaching hoses and turning the power sources on and off. Keep the tool bits sharp.

14. **Operating Instructions.** To operate:

a. rotate the latch on the breaker downwards (away from the foot), insert the proper bit, and lock it in by pulling the latch up;

b. connect the hoses and turn on the power source as described in the previous sections;

c. place the bit firmly on the surface to be broken and squeeze the trigger to start;

d. start by breaking a hole in the surface, once this hole is made start cracking portions of the surface into the original hole in a spiral fashion; and

e. for harder material, start with smaller bites and increase until the pieces require increased time to break.

NOTE: The tool will stick if too large a bite is taken. The tool will drill into the material without fracturing it.

15. **Accessories**. The following accessories can be used with both breakers: a clay spade, an asphalt cutter, a moil point, a ground rod driver, and a chisel point.

IW12 HYDRAULIC IMPACT WRENCH

16. **General**. The impact wrench operates at 2000 rpm with an hydraulic flow of 19 litres per minute. The wrench is designed for 19 mm square drive sockets and accessories. It is used for the removal of fastenings and for wood auger boring.

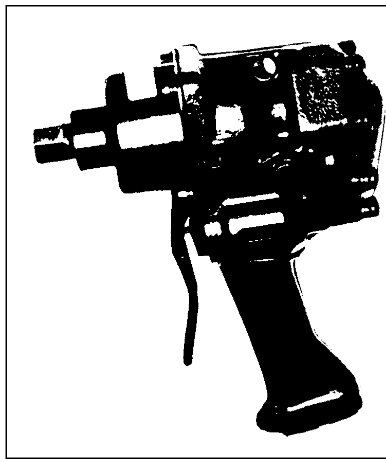


Fig 6-4-6 IW12 Hydraulic Impact Wrench

17. **Precautions**. The following safety precautions apply:

a. observe all safety precautions for attaching hoses and for turning power sources on and off;

b. if the hammer pin breaks frequently, the impact mechanism is being overdriven;

c. do not use as a hammer drill or for metal drilling, and

d. if used for a long period of time, the lower setting of torque range (407-1622 Newton-metres) is to be used.

18. **Operating Instructions**. To operate:

a. connect the tool to the power source;

b. select the direction of impact with the rotation valve located on the left side of the wrench. Push the lever forward (to the front) for clockwise motion and backward (to the handle) for counterclockwise motion, and

c. start and stop the wrench by squeezing and releasing the trigger.

HD45 HYDRAULIC HAMMER DRILL

19. **General.**

a. The hammer drill operates with 25 mm and 50 mm diameter carbide bits.

b. The rotation of the drill is reversible and the speed can be varied by selecting the lever setting (at the foot of drill):

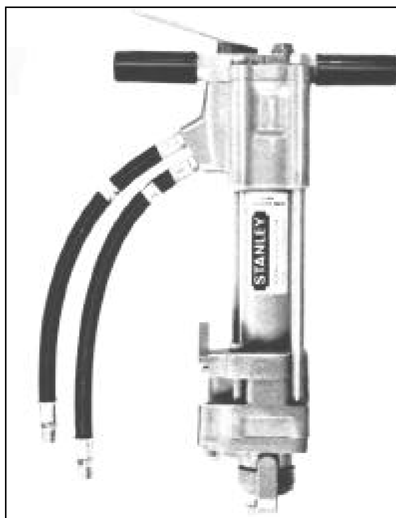


Fig 6-4-7 HD45 Hydraulic Hammer Drill

(1) the vertical up position - neutral,

(2) the horizontal position - "on position", the drill will operate in the direction the lever is pointing, and

(3) the further the lever is pushed down the faster the speed.

c. The best initial setting is between the vertical and horizontal positions.

d. Apply pressure and begin drilling while keeping the drill bit centred in the hole.

HG60 HYDRAULIC GRINDER

20. **General**. The HG60 hydraulic grinder is a compact, lightweight, quiet, and easy to use system. Its slim design makes it ideal for inside diameter pipe grinding and clean-up. It features a fully adjustable wheel guard and feathering trigger.

Fig 6-4-8 HG60 Hydraulic Grinder

21. **Safety Precautions**. The following safety precautions apply:

a. to tighten or loosen the wheel nut, hold the shaft with a second wrench on the flats behind the wheel and tighten securely; do not attempt to tighten or loosen by impact;

b. assemble the tool correctly and completely and adjust properly; do not operate if it is damaged, improperly adjusted or assembled;

c. maintain proper footing and balance at all times; avoid over-reaching;

d. disconnect the hydraulic power source before inspecting or cleaning the grinder. Accidental engagement of the grinder can cause serious injury;

e. connect hoses to the tool hose couplers before energizing the hydraulic power source. Make sure all hose connections are tight;

f. hold the grinder firmly with both hands when running. Keep the rotating wheel away from all parts of the body;

g. when starting the grinder, keep the wheel off all surfaces;

h. make sure the wheel has stopped before setting down the tool or carrying it; and

j. keep the handles clean and free of fluid at all times.

22. **Operating Instructions**. To operate:

a. connect the hoses from the hydraulic power source to the tool fittings or quick disconnects;

b. observe the flow indicators on the hose couplers to ensure the flow is in the proper direction. The female coupler on the tool is the inlet (pressure) coupler;

c. ensure the circuit pressure hose (with the male quick disconnect) is connected to the port farthest from the trigger and ensure the circuit return hose (with the female quick disconnect) is connected to the port closest to the trigger;

d. squeeze trigger momentarily. If grinder does not operate, the hoses may be reversed;

e. grip the grinder with both hands at all times during startup and operation;

f. start the grinder with the wheel away from the work surface, and

g. initiate the hydraulic flow slowly, gradually increasing the flow to a level that produces the desired efficiency but allows the operator to maintain full balance and control.

Important: Starting the hydraulic grinder with full hydraulic flow can push the operator off balance and can result in severe personal injury.

SK58 SINKER DRILL

23. **General**. The SK58 sinker drill is designed for utility construction work, blast hole drilling, leak detection for gas drilling and dowel drilling. It is intended for heavy-duty applications and features an adjustable rotation and feathering trigger for easy starting. The SK58 is available in either air or water flushed versions.

24. **Safety Precautions**. The following safety precautions apply:

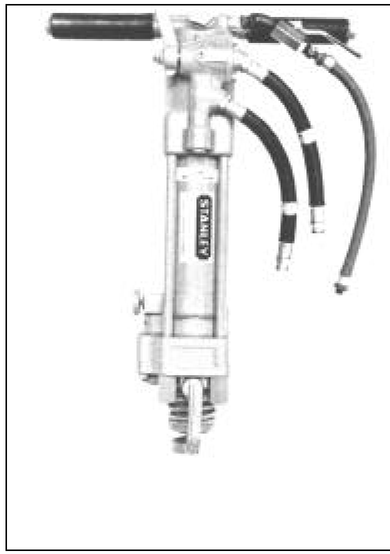


Fig 6-4-9 Sk58 Sinker Drill

a. review all instructions carefully before operating the drill;

b. wear safety shoes as well as other protective equipment such as goggles, ear and head protection.

c. never start the sinker drill lying on the ground;

d. be sure all hose connections are tight. A loose air hose may disconnect completely from the sinker drill and whip freely, injuring the operator and bystanders; and

e. never disconnect a pressurized air hose. Before disconnecting a hose, shut-off the air at the compressor and bleed the sinker drill.

25. **Operating Instructions.** To operate:

a. install the appropriate drill steel for the task;

b. place the drill steel firmly on the surface to be drilled. Do not operate the sinker drill without the drill in contact with the work surface;

c. to reduce "walking the drill”:

    (1) depress the trigger slowly, the piston will cycle at slow speed without tool bit rotation. This will allow a hole to be started before full power is initiated, and

    (2) rotating the motor control lever straight up will shut off all rotation allowing the operator to establish a starting hole prior to full power application.

d. operate the drill with the lever depressed halfway between fully on and the straight up OFF position.

e. when drilling deep holes, stop drilling every 10 to 20 seconds to allow the receiver and air hoses to charge, and provide a short burst of air to expel excess debris from the hole.

f. keep the drill steel centered in the hole.

g. ensure an adequate flow of air remains in the tool system or the drill steel may bind in the hole; and

h. apply adequate feed pressure to the sinker drill to maintain optimum drilling performance.

26. **Accessories**. Carbide rock bits (4-5 cm diameter); and steel drills (2.5-3 cm diameter and 30.5-244 cm long) can be used with this system.

CHAPTER 7

ENGINEER HEAVY EQUIPMENT

SECTION 1

GENERAL

INTRODUCTION

1. Most engineer units are equipped with various types of heavy equipment. Engineers are required to plan and supervise the employment of heavy equipment, and shall know the types available, characteristics and capabilities. The aim of this chapter is to provide a brief description of the equipment available and how they are used.

2. Engineer heavy equipment must be differentiated from engineer equipment (see Chapter 9). Engineer heavy equipment consists of equipment, vehicles and their attachments, which are primarily used for horizontal and vertical construction and maintenance tasks. Some examples of heavy equipment are: dozers, graders, scrapers, loaders, cranes, snow clearing equipment, and excavators.

GENERAL SAFETY PRECAUTIONS

3. Engineer heavy equipment operations are characterized by large, heavy, unwieldly vehicles, with restricted fields of vision, maneuvering often in the presence of personnel working on foot, and often at night. It is a very dangerous environment. The following safety precautions will help prevent accidents. Additional precautions may be necessary depending on the conditons at the task site and the particular machine being used.

4. Operators shall:

   a. be familiar with the operator's manual and operate the machine within its capabilities and limits;

   b. be familiar with the work site - above ground (eg. weather conditions and obstructions), at ground level (eg. presence of obstacles) and below ground (eg. underground utilities);

c. conduct a walk around inspection of the machine to check for:

(1) coolant, fuel and hydraulic line leaks,

(2) debris left in the engine compartment,

(3) the condition of attachments (cutting edges and teeth),

(4) damaged components both inside and outside of the operator's cab,

(5) clear visibility (windows, mirrors and running lights), and

(6) personnel in the machine's immediate area.

d. use seatbelts;

e. obey hand signals and ground guide;

f. check for warning tags (servicing and non-serviceable) on the steering wheel or starter switch indicating that the machine should not be used or even moved;

g. test all controls for proper operation prior to moving the machine;

h. ensure that unattended equipment is shut off and all attachments lowered to the ground;

j. park equipment (utilizing the parking brake) on level ground when possible, otherwise at right angles to any slope with wheels blocked;

k. never allow riders on the outside of the machine or personnel to stand in the pivot area of an articulated machine while the engine is running;

m. shut off the machine during refueling;

n. never move a load over personnel or vehicles;

p. carry the attachments low for good stability and visibility while travelling;

q. allow clearance for overhead dangers, such as overhanging trees and banks and overhead wire, especially high voltage lines;

r. keep the equipment back from the edges of banks and excavations, or if it cannot be avoided, face the machine towards the bank's edge while operating;

s. on haul roads, give loaded vehicles the right-of-way; and

t. when loading and unloading a machine for transport:

(1) load and unload only on level ground;

(2) block the transport vehicle's wheels;

(3) use ramps with sufficient strength, height and angle;

(4) ensure the trailer bed is free of all slippery substances, such as clay, oil, or snow;

(5) know the manufacturer's recommended procedure for loading and unloading the machine;

(6) only load and unload a machine with the assistance of a ground guide, and

(7) ensure the machine is properly secured before moving the trailer.

5. **Danger:** If your machine comes in contact with a charged line, stay in the cab. Do not allow anyone close to the machine until the power has been cut off or until contact with the line has been broken.

SELECTION OF HEAVY EQUIPMENT

6. Most earthmoving equipment can handle a wide variety of tasks in different conditions, but there will always be a best method and an optimum type of machine for each task. The choice of the right method and type of equipment for a task is a complicated problem involving many factors, including:

a. site conditions;

b. tactical situation;

c. availability of the equipment and attachments;

d. time available;

e. operator training and supervision; and

7. The following sections of this chapter describe the general capabilties and uses for each type of equipment. Annex A lists various heavy equipment tasks and the suitable heavy equipment.
A "rule-of-thumb" guide for the most efficient choice of earthmoving equipment is shown on the next page:

Distance	Heavy Equipment
30 m	Optimium dozer haul distance
0-100 m	Dozers, tracked or wheeled
0-300 m	Loaders in the "load and carry" role
100-450 m	Towed scrapers
300-1500 m	Self-propelled scrapers
Over 1500 m	Haul vehicles with excavators or loaders

Fig 7-1-1 Earthmoving Rule of Thumb

8. **Tracks Versus Wheels.** In addition to selecting the correct type of heavy equipment for a task, it is sometimes necessary to choose between a tracked or wheeled machine.

a. Tracked tractors have the advantage of greater traction efficiency and thus greater digging/pushing capacity. They are, however, slower and require road transportation. They can cause considerable damage to the ground surface particularily when turning. Tracked tractors require more maintenance and cause considerable operator fatigue because of the vibration. These factors greatly affect the output of the machine.

b. Wheeled tractors have slightly less digging capability however they have a faster cycle time. They can move quickly without requiring transportation, and are therefore suited to provide mobility support for combat forces. Wheeled tractors cause less operator fatigue and in general, require less maintenance. The exception being:

(1) in hot climates where the tires are exposed to bright sunshine, and

(2) on rocky surfaces or in timbered areas where the tires may be punctured.

HEAVY EQUIPMENT OUTPUT

9. Heavy equipment output is a function of a variety of factors, including:

a. selected heavy equipment and attachments;

b. task and site conditions;

c. method of employment and haul distances; and

d. operator efficiency and supervision.

10. Heavy equipment output formulae and factors are included and explained in manuals B-CE-320-002/PF-001 and B-GL-320-006/FP-001.

SECTION 2

EARTHMOVING EQUIPMENT

GENERAL

1. Earthmoving equipment is used for digging or picking up earth or other materials, moving or carrying it elsewhere, and stockpiling or spreading it. The earthmoving machines discussed in this section are dozers, excavators, loaders, backhoes (industrial tractors), graders, scrapers and dump trucks.

TRACKED DOZERS

2. A dozer is a tractor with a blade mounted. Dozer blades are of three general types, straight bulldozer (right angle to the tractor), angle (angled relative to the forward motion of the tractor) and universal (“U”). Tracked dozers are used for digging, pushing and spreading material for short excavation (up to 100 m), and as auxiliary machines to other construction equipment. A prime mover is used to move tracked dozers between work sites.

3. The main characteristics that categorize tracked dozers are horse power available, track width, weight and performance (output capability). Dozers may be equipped with an armoured cab. Dozers in the Canadian Forces are divided into three categories as follows:

   a. Heavy - D8, D9;

   b. Medium - D6, D6D, D7, TD15, TD20, Case 1450; and

   c. Light - D4, D5.

4. **Dozer Attachments.** Dozers are normally equipped with the following attachments:

   a. a straight bulldozer blade (Fig 7-2-1), angle blade (Fig 7-2-2) or universal blade (Fig 7-2-3),

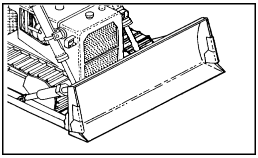


Fig 7-2-1 Striaght Blade

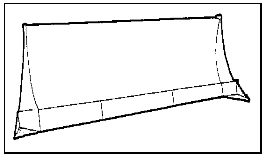


Fig 7-2-2 Angle Blade

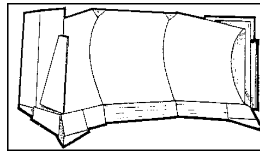


Fig 7-2-3 Universal Blade

b. a tilt mechanism, and

c. a ripper or winch.

5. For specific jobs, dozers may be equipped with the following attachments:

a. a brush rake,

b. a stump splitter,

c. pusher blocks,

d. a side crane (for pipelines),

e. a backhoe, and

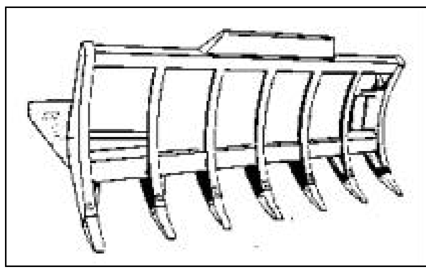


Fig 7-2-4 Bush Blade

f. a power control unit (PCU) for scrapers.

6. **Heavy and Medium Dozers.** Heavy and medium dozers are suitable for the following tasks:

a. removing stumps and roots, tree felling and clearing, and rock removal (heavy dozers are used for large rocks and trees);

b. digging road, airfield and excavating (cut and fill) ;

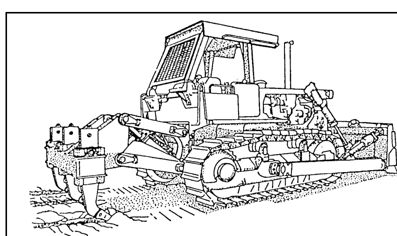


Fig 7-2-5 Heavy Dozer with Ripper

c. towing scrapers and compactors;

d. spreading and stock-piling material;

e. filling excavations;

f. moving obstacles, rubble, debris and heavy snow; and

g. breaking up (ripping) roads.

7. **Medium Dozers**. In addition, medium dozers are suitable for the following tasks:

a. digging vehicle and weapon emplacements; and

b. digging antitank ditches.

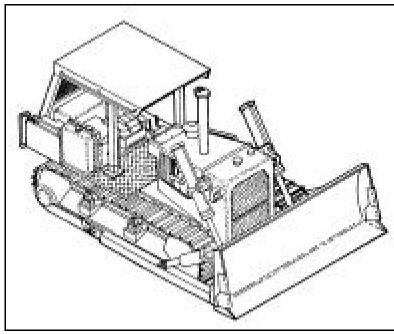


Fig 7-2-6 Medium Dozer

8. **Light Dozers**. Light dozers are suitable for: rollers.

a. filling craters and excavations;

b. spreading material;

c. clearing light scrub, rubble and light snow; and

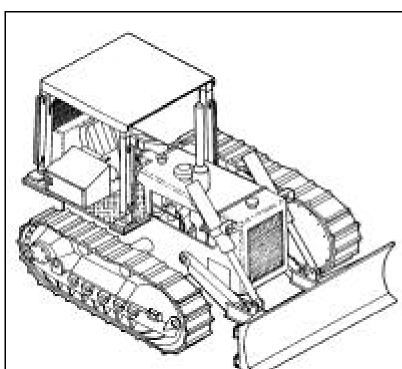


Fig 7-2-7 Light Dozer

d. towing a rotary plow, or compactors or snow

WHEELED DOZERS

9. The wheeled dozer is a wheeled tractor with a blade mounted. The primary use of wheeled dozers is rapid, short haul excavation (digging, pushing and spreading earth and snow) at distances of up to 100 m.

10. Wheeled dozers are categorized as light, medium and heavy by horsepower available, tire size, weight and performance as measured by output capability. Their high speed road mobility and high work output are ideal for supporting combat forces in the advance on the battlefield.

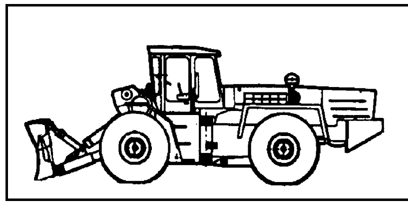


Fig 7-2-8 Zettlemeyer Wheeled Dozer

EXCAVATORS

11. An excavator digs and discharges material with a single bucket suspended from or mounted on a boom. It can be self-propelled, mounted on crawler tracks, or wheels, which allows it to move between sites.

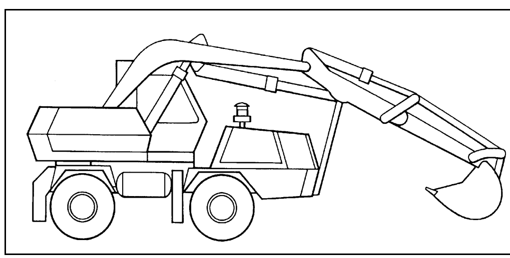


Fig 7-2-9 Typical Wheeled Excavator

12. The excavator may be equipped with the following attachments:

a. a wrist-o-twist (permits the bucket to be twisted 40 degrees to either side of centre);

b. a general purpose, ditch forming, light duty or severe duty (frost) bucket;

c. a face shovel;

d. a pavement breaker;

e. a vibratory compactor;

f. a hydraulic impact hammer;

g. an air/hydraulic drill;

h. a grapple; and

j. a thumb.

13. The excavator is suited for the following jobs:

a. digging antitank ditches, field fortifications and vehicle pits;

b. excavating building construction sites and sanitation facilities;

c. excavating and improving water crossing sites;

d. loading haulage vehicles;

e. light lifting tasks; and

f. road and airfield construction and repair, including:

(1) breaking pavement,

(2) excavating craters and culverts,

(3) ditching, and

(4) compacting soil.

LOADERS

14. Loaders or Front End Loaders (FELs) are self-propelled tractors equipped with a front scoop bucket. The FEL loads material into the scoop through the machine's forward motion, it then lifts, transports and discharges the material into a stockpile or onto a vehicle (eg. a dump truck). Loaders can be either wheeled or tracked and vary in size and capacity

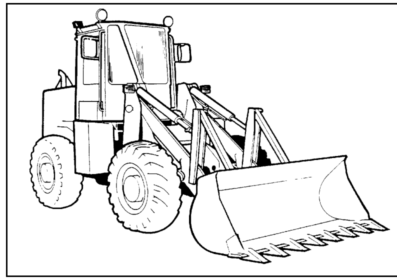


Fig 7-2-10 Typical Loader

15. Attachments. Loaders are normally fitted with a multi-purpose (4 in 1) bucket and may be equipped with the following attachments:

a. a backhoe bucket;

b. a forklift to replace the detachable bucket;

c. a pavement breaker;

d. a sweeper, snow bucket or snow blower; and

16. **Wheeled Loaders.** A wheeled loader is capable of rapidly loading material. It has a significant radius of operation before it must be transported on a prime mover. Wheeled loaders are suitable for the following tasks:

a. excavating defensive positions, support weapon emplacements, command posts and field sanitation facilities;

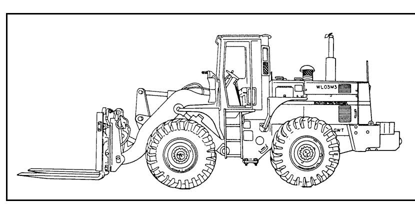


Fig 7-2-11 Wheeled Loader with Forklift Attachment

b. loading haulage vehicles;

c. lifting using forklift and crane attachments;

d. loading hoppers during crusher operations;

e. excavating and back-filling;

f. and cleaning and removing rubble, debris and heavy snow.

17. **Tracked Loaders**. A tracked loader is capable of loading material in areas which are not accessible to wheeled loaders and quarry operations, however a prime mover is required to move from site to site. Tracked loaders are suitable for the following tasks:

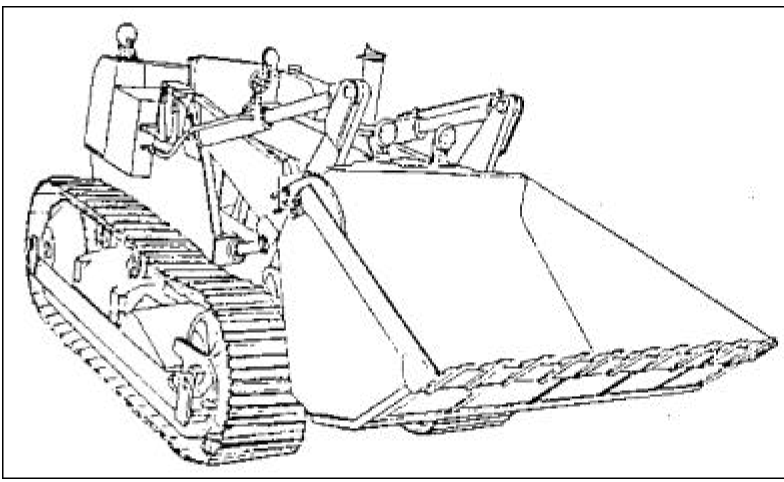


Fig 7-2-12 Tracked Loader

a. loading haulage vehicles;

b. backfilling and excavating;

c. clearing rubble, debris and snow; and

d. loading hoppers for crusher operation.

INDUSTRIAL TRACTOR

18. The industrial tractor is an agricultural type tractor normally fitted with a scoop bucket in front and a small backhoe bucket at the rear.

19. The backhoe bucket may be replaced with a variety of hydraulically operated attachments, including a back spreading blade, a hydraulic earth auger, a vibrapacker, or pavement breaker. The front scoop bucket may be replaced with a 4 in 1 bucket, a snow bucket or a sweeper. A small portable backlift and ripper teeth can be attached to the bucket.

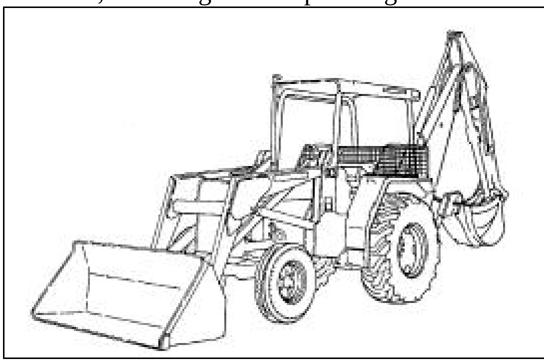


Fig 7-2-13 Typical Industrial Tractor

The industrial tractor is normally used for:

a. excavating individual and support weapon battle trenches and small command posts;

b. small excavating and backfilling, including field sanitation facilities;

c. light landscaping, levelling and ditch maintenance;

d. clearing debris and light snow;

e. drilling holes up to 1.5 m deep; and

f. loading, unloading and carrying of small stores.

GRADERS

21. A grader is a self-propelled machine with an adjustable blade positioned

Between the front and rear axles to cut, move and spread materials, usually to grade. Graders may have a rigid or articulating frame. The articu-lating frame decreases the turning radius and increases production.

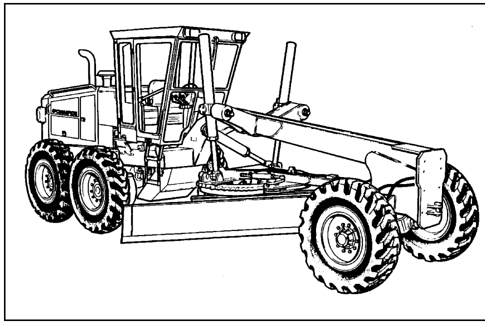


Fig 7-2-14 Typical Grader

22. Graders may be equipped with the following attachments:

a. a V-plow for snow removal

b. a wing plow to cut down high snow banks;

c. a scarifier to loosen hard soils;

d. a rear mounted ripper; and

e. a front mounted dozer blade.

23. Graders are suitable for the following horizontal con-struction tasks:

a. cutting and maintaining ditches;

b. scarifying, levelling and shaping surfaces;

c. stripping of light soil;

d. clearing snow; and

e. spreading fill in layers of uniform thickness.

SCRAPERS

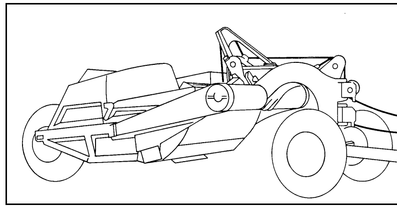


Fig 7-2-15 Typical Towed Scraper

24. Scrapers are large earthmoving machines capable of digging, loading, hauling, dumping and spreading material. They can be either towed or self-propelled. They are particularly useful on large earth-moving tasks such as airfield or road construction which involves numerous cuts and fills. Scrapers make shallow cuts while loading, transport large loads for considerable distances at relatively high speeds, and spread materials in a thin uniform layer. They operate most effectively over hauling distances 100-450 m for towed scrapers and 300-1500 m for self-propelled scrapers. Motorized and towed scrapers usually require a dozer as a puller during the loading cycle. Self-propelled scrapers can work alone and self-load, but only at a greatly reduced output.

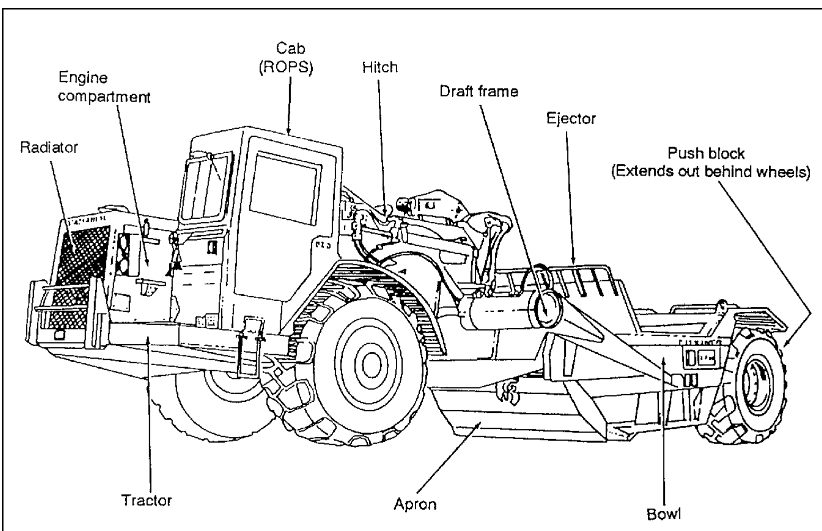


Fig 7-2-16 Typical Self-Propelled Scraper

25. Scrapers are not held by engineer units at this time, but can be made available through rental or other agreements.

DUMP TRUCKS

26. There are a variety of dump trucks in service, both military and commercial pattern, ranging in size from 5-Ton to 20-Ton. They may be powered by diesel or gasoline engines with varying load capacities. Dump trucks normally dump their load at the rear of the vehicle, however some types tip the load over the side. They can also haul a variety of trailers.

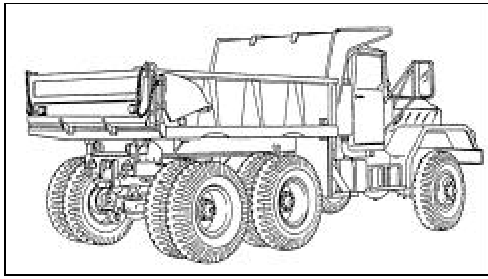


Fig 7-2-17 Typical Dump Truck

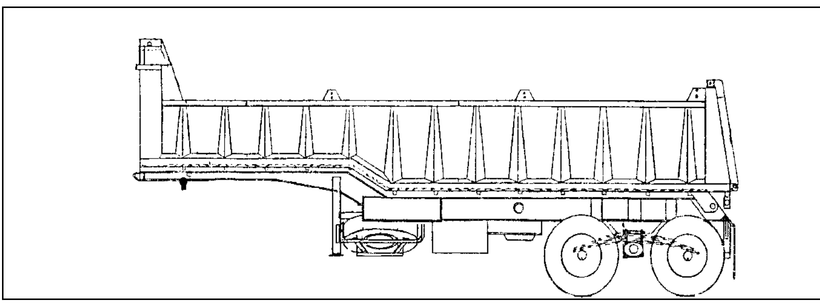


Fig 7-2-18 30 Ton Dump Trailer

27. Dump trucks are suited for the following jobs:

a. hauling and spreading earth, rock, aggregate and construction material for airfield, road or other construction and maintenance tasks;

b. hauling mines for minefield laying, and towing a mechanical minelayer; and

c. hauling engineer and defence stores

SECTION 3

CONSTRUCTION EQUIPMENT

GENERAL

1. Construction equipment covers a very wide range of machines which may be needed on a task site to complete construction, such as:

   a. rock crushers;

   a. compaction equipment;

   b. paving and mixing equipment; and

   c. pile driving equipment.

ROCK CUSHERS

2. Rock crushers are machines used to provide graded aggregate for horizontal construction projects. Rock crushers use crushing equipment (either pressure or impact) to reduce rock or stone to smaller sizes, called crusher-run material. Screens separate the crusher-run material into appropriate grades. Washing equipment is used to wash the crusher-run material to remove the left over fines. Conveyor belts and rock drills are also used. Rock crusher operations requires the employment of other types of heavy equipment, including loaders and dump trucks.

COMPACTION EQUIPMENT

3. Compaction equipment is used to increase the stability and durability of all hardstanding areas by increasing the density of the material. There are various types of equipment which can be used depending on the material, moisture content and job requirement.

4. **Rollers**. Rollers can be either self propelled or the towed type. Either type may be made available to be used by engineer units and are described below.

a. **Sheepsfoot Roller.** Used mainly for compacting cohesive soils of low moisture content, it is normally towed by a tracked tractor

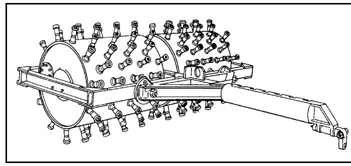
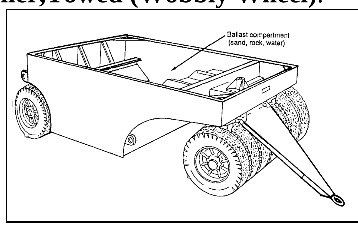


Fig 7-3-1 Sheepsfoot Roller

b. **Pneumatic Tired Roller,Towed (Wobbly Wheel)**. Is used for compacting fine grained soils, sub-bases, bases and surfaces. It is normally towed by a wheeled tractor.



Pneumatic Tired Roller, Towed

c. **Vibrating Roller**. This roller can be used on non-cohesive soils. It can also be used on materials containing up to a 50 percent cohesive element providing water content is not excessive. It can be towed by either a wheeled or tracked tractor.

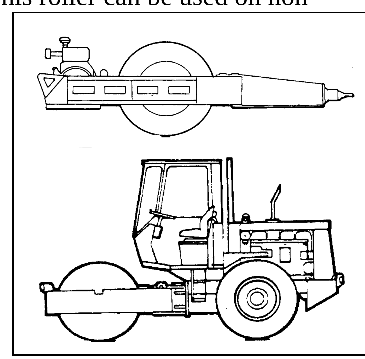


Fig 7-3-3 Vibrating Roller (Towed and Self Propelled)

5. **Snow Roller**. The snow roller is used in the construction of snow compacted airstrips. They are used in sets of three with removable steel plates to adjust weight. It is normally towed by a tracked tractor and is air droppable.

6. **Water Distributor**. Water distributors are vehicles or trailers capable of distributing water evenly over a surface. They are required during road and airfield construction to improve compaction by increasing moisture content. They are also used to control dust on earth roads.

PILE DRIVING EQUIPMENT

7. The pile driver is used to drive bearing or sheet piles into the ground for the construction of buildings and supporting structures. It consists of a hammer and a support system for the hammer and pile. The Canadian Forces presently uses the Grove AT865 crane with a Delmag D8-22 5-tonne diesel-powered hammer which consists of a cylinder containing a moving piston or ram.

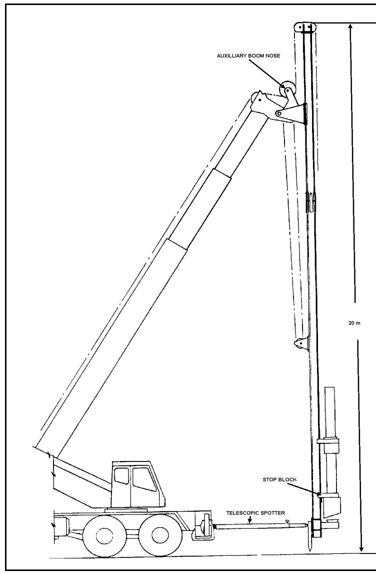


Fig 7-3-4 Crane with Pile Priver

8. **Safety**. General safety procedures for heavy equipment operation, as well as those specific for the crane and pile driver must be adhered to.

9. **Operation**. The pile driver is operated by a three man crew (crane operator, hammer operator and detachment commander). It takes approximately four hours to set up the pile-driver from scratch or two hours if it is already prepared on a lowbed. The rate of pile driving depends on the soil and the site conditions. The normal rate of driving is five minutes for a 10 m pile, however the constant moving of the crane slows the process down. For more detail on pile driving procedures, refer to Chapter 14. Refer to the operator manual for specific pile driver operating procedures.

SECTION 4

MATERIAL HANDLING EQUIPMENT

GENERAL

1. Material handling equipment includes equipment used to load, unload and carry materials such as mines, bridging loads, defence stores, pallets and containers, etc.

CRANES

2. There are various types of cranes available, including an airportable crane. However, the crane most commonly used in engineer units is the Krupp crane which has a hydraulic telescopic boom. There are boom extensions of 8 and 13 m. It is mounted on a wheeled chassis which enables it to move quickly between sites. It has a maximum lift capacity of 19.9 tonnes at a working radius of 4 m and 360 degree rotation.

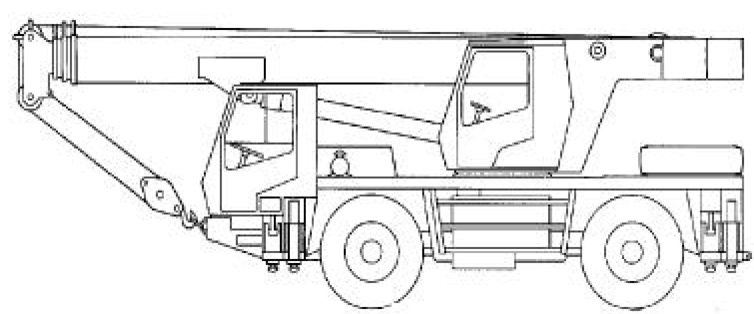


Fig 7-4-1 Krupp Crane

3. The other crane available is the Grove AT865 with greater lifting capability and a longer boom. The lift capacity is 41.1 tonnes at a working radius of 4.5 m with a 360 degree rotation.

20. Cranes are suitable for the following tasks:

a. lifting loads such as containers, pallets, vehicles, construction material, boats, bridging and rafting loads;

b. loading and unloading vehicles;

c. lifting loads during construction tasks, such as steel girders; and

d. pile driving.

5. All Field Engineers shall be familiar with hand signals used to guide the crane operator. Before the task, the crane operator will determine the best location for the crane, the maximum lift based on the load and the boom extension required, and brief the ground crew on the hand signals to be used.

FORKLIFTS

6. Forklifts are self-propelled wheeled vehicles with moveable forks mounted on the front, which are used for handling palletized loads. Some forklifts are equipped with zoom boom forks.

21. The following types of forklifts may be available:

a. **Warehouse Pattern Forklifts.** These vehicles have small wheels and are designed to work indoors in warehouses or outside on hard standing The lift capabilities will vary with the size of the vehicle. These forklifts can be gasoline, propane or diesel powered.

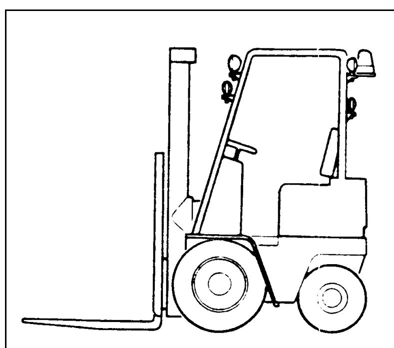


Fig 7-4-2 Warehouse Pattern Forklift

b. **Rough Terrain Forklifts**. These vehicles are designed to work outside. They are well suited to handling palletized stores in engineer mine dumps. Maximum lift will depend on the vehicle load capacity;

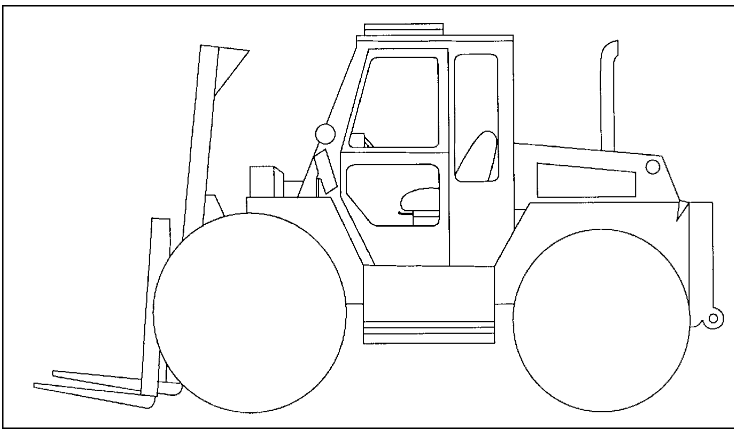


Fig 7-4-3 Rough Terrain Forklift

SECTION 5

TRANSPORT EQUIPMENT

GENERAL

1. Engineers also need vehicles capable of transporting heavy equipment (particularly tracked dozers/loaders) between work sites and on administrative road moves. Transport equipment includes:

a. tractor trailer units; and

b. tiltbed trailers.

TRUCK TRACTOR AND TRAILERS

2. **Tractor Trailer.** The current tractor trailer unit is the HLVW 20-Ton tractor with a 35-Ton variable deck trailer (front and rear gooseneck) (Fig 7-5-2). It is suited for transporting engineer stores and equipment on long and short hauls. It has some cross country capability and can be used as a recovery vehicle, if necessary.

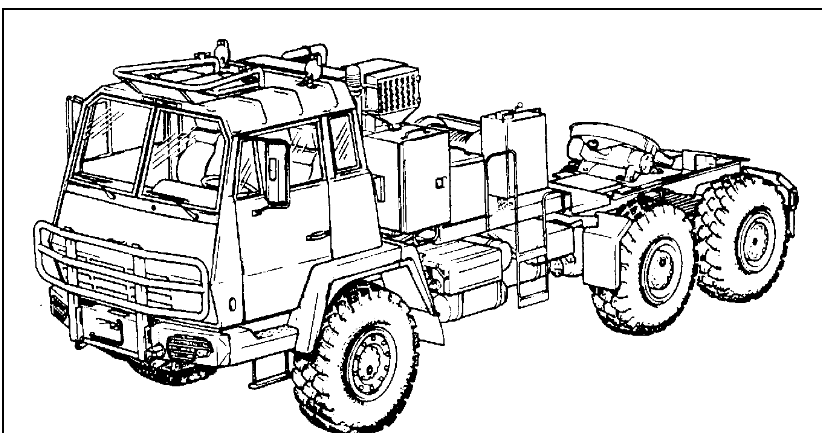


Fig 7-5-1 HLVW 20 Ton Tractor

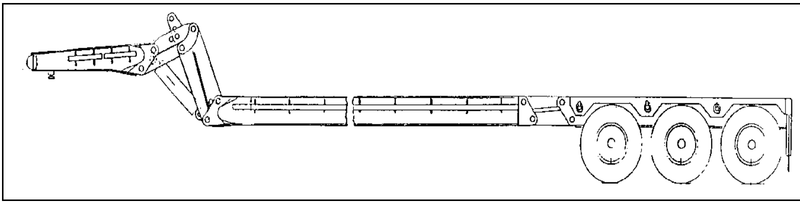


Fig 7-5-2 35 Ton Variable Deck Trailer

3. **Tiltbed Trailers**. Tiltbed Trailers (Beavertails) can carry loads up to 15 tons are designed for ease of loading so it can be pulled by a 5-Ton dump truck. The tiltbed trailer is suited for the following tasks:

a. transporting APCs;

b. hauling light engineer equipment and attachments under 15-tons;

c. recovering unserviceable vehicles; and

d. hauling bulk engineer stores and defence stores.

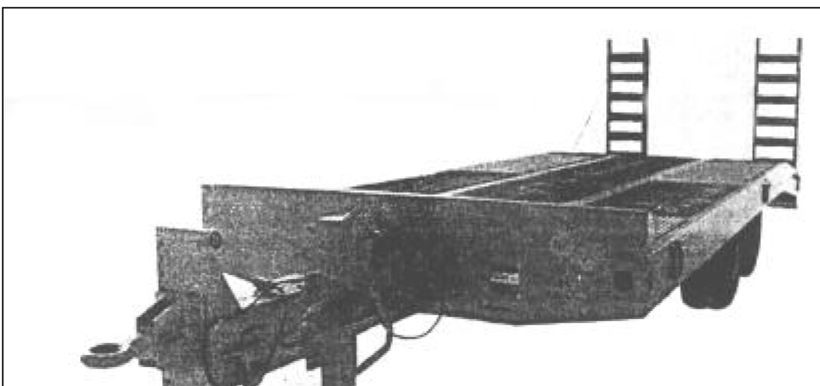


Fig 7-5-3 Tiltbed Trailer (Beavertail)

ANNEX A

HEAVY EQUIPMENT SELECTION

Ser	Operation	Heavy Equipment	Remarks
1	Clearing and grubbing- scrub and trees up to 750 mm diameter	a. Dozer, tracked	
		b. Tractor with heavy duty winch	Trees up to 300 mm diameter.
		c. Two tracked dozers with anchor chain	Trees up to 600 mm diameter.
		d. Excavator	
2	Grubbing stumps and clearing roots	a. Dozer, tracked or wheeled	The most efficient attachment is the dozer blade.
		b. Tracked tractor with ripper	
		c. Excavator	
3	Clearing felled timber	a. Dozer, tracked or wheeled	
		b. Dozer with front mounted rake	
4	Clearing boulders	Dozer, tracked	May have to use ripper attachment to loosen boulders.
5	Clearing debris and rubble	a. Dozer, tracked or wheeled	Wheeled dozers are efficient on asphalt or concrete.
		b. Tractor with heavy duty winch	For clearance of large objects.
		c. Loaders, tracked or wheeled	For moving and loading small debris and rubble into haulage vehicles for removal.
		d. Excavator	

Ser	Operation	Heavy Equipment	Remarks
6	Clearing snow	a. Grader	Lanes only.
		b. Loader wheeled	For moving and loading snow.
		c. Dozer, tracked or wheeled	Wheeled dozers for use on asphalt or concrete.
		d. Snowplough or blower fitted to tractor or other suitable vehicle	
7	Stripping - topsoil etc which covers desirable material	a. Dozer, tracked or wheeled	Angledozer for clearing long narrow lanes up to 4 m wide, leaving windrows of material on each side. Slot dozing for more extensive areas, limit 100 m haul. May have to use ripper attachment to break roots and frozen ground.
		b. Scraper, towed or motorized	Haul distance 100-450 m for towed scraper, 300-1500 m for large motorized scraper.
		c. Grader	Only light stripping.
		d. Excavator	Stripped soil hauled away.
8	Earth movement (cut and fill) and embankments	a. Dozer, tracked or wheeled	Optimum haul does not exceed 30 m. Sidehill cuts and cuts down vertical faces for roads.
		b. Scraper, towed or motorized	Towed scrapers are best for hauls 100-300 m and motorized scrapers for hauls 300-1500 m. Pusher required for heavier soils.

Ser	Operation	Heavy Equipment	Remarks
8 (cont)	Earth movement (cut and fill) and embankments (cont)	c. Grader	Suitable for building shallow road embankments not more than 0.5 m high across flat or gently undulating land by cutting longitudinal drainage ditches at each side.
		d. Excavator with face shovel, and haulage vehicles	Suitable for two types of excavation: (1) Where material cast direct from cut to fill, eg, deep side-hill cuts or clearing thick overburden for a road, and (2) Excavation involving long hauls by haulage vehicles, ie, embankments built from distant cuts or borrow pits.
		e. Excavator with backhoe bucket, and haulage vehicles	For bulk excavation below track level. Also for high lifts such as placing in bins of screening plant.
		f. Loader, tracked or wheeled and haulage vehicles	Suitable for short distances, up to 300 m, using 'load and carry', and for loading haulage vehicles for long hauls over 1500 m.
9	Consolidated materials, difficult to dig, eg, hardpan shale and rock All materials must be loosened by rippers or explosive before handling.	a. Dozer, heavy tracked with ripper	Suitable for moving, dumping, and spreading loosened material for hauls of 30-100 m. Used also to stockpile materials.
		b. Excavator with face shovel or backhoe bucket, and haulage vehicles. Rock buckets should be fitted	See Serials No 8(d) and 8(e). Efficiency of these units is much reduced when handling this type of material. Only the larger sizes of excavators are suitable in these conditions. Service excavators are likely to be ineffective.
		c. Scraper with push tractor	See Serial No 8(b). Scraper's efficiency is reduced for this type of material. Special heavy equipment is required.

Ser	Operation	Heavy Equipment	Remarks
10	Ditching - Constructing open ditches for drainage of surface water	a. Grader	Suitable for open V ditches in soil free from rocks and roots.
		b. Dozer, tracked or wheeled	Can cut rough V-shaped or shallow U-shaped ditches.
		c. Excavator with ditch forming bucket	Particularly useful for deep wide ditches, or for clearing or enlarging existing ditches or canals.
		d. Excavator with hydraulic breaker	A heavy hydraulic breaker can also be fitted for breaking out rock in trench bottoms and a grab which can remove broken rock without straddling the trench.
		e. Backhoe	
11	Trenching - Excavating deep narrow trenches with vertical sides	a. Multi-bucket or chain-cutter type trencher	Suitable for soils containing neither large rocks nor roots.
		b. Excavator	Suitable for deeper and wider trenches in heavier soils.
		c. Backhoe	
12	Backfilling - re-placing material in a trench or small exca-vation	a. Dozer, tracked or wheeled	Angledozer best for backfilling trenches. Bulldozer best for pits and other excavations.
		b. Grader	Can be used for side casting windowed material back into an open ditch.
		c. Loader, tracked or wheeled	Useful for backfilling excavations from adjacent spoil dumps.

Ser	Operation	Heavy Equipment	Remarks
13	Sloping and battering - Sloping banks and sides of excavations	a. Grader	Suitable for accurate battering of banks up to heights of 2.5 m.
		b. Excavator	Suitable for cutting back and trimming deep steep faces and for sloping the sides of embankments and excavations.
		c. Dozer, tracked	Can do rough work only. Suitable in cuttings rather than fills.
14	Spreading - Distribution of fill in layers of uniform thick-ness	a. Scraper, towed or motorised	Suitable for hauling and spreading thin layers of material. For lengths of haul see Serial No 7(b)
		b. Grader	Used for spreading and win-dowing material of a work-able nature, not containing shattered rock or boulders.
		c. Dump trucks	By controlling the angle of dump and the opening of the tail gate, can spread their loads to a limited extent to assist final even spreading by another machine.
		d. Dozer, tracked or wheeled	Best machine for initial spreading of workable materials, including shattered rock, which have been dumped by haulage vehicles.
15 1	Compaction - Consolidating fill, subgrade, or base course materials	a. Sheepsfoot rollers	Used mainly for compacting cohesive soils of low mois-ture content. Tamping rollers are now mainly used because sheepsfoot rollers tend to destroy the soil structure.
		b. Pneumatic-tyred roller	Used mainly for compacting fine grained soils, sub-bases, bases and surfaces.

Ser	Operation	Heavy Equipment	Remarks
		c. Steel wheeled roller	Used mainly where crushing action is needed. Also for ini-tial rolling and finish rolling of waterbound macadam, as-phalt, and bituminous pavement
		d. Vibrating roller	For compacting non-cohesive soils, sub-bases and bases. It can now be used safely on materials containing up to 50% cohesive element provided water content is not excessive.
		e. Grid roller	Used for compaction of rock and chalk.
		f. High speed compactor	Used for embankments compaction.
		g. Vibrating plate com-pactors and tampers	Used at sites too restricted for rollers.
16	Cambering, trimming and shaping to formation level	a. Grader	Best machine for final camber. Grader with scarifier used to loosen and shape top layer of an earth road or runway.
		b. Dozer, tracked or wheeled	Can provide camber during initial excavation for road formation, but cannot accurately do shaping.
		c. Scraper, towed or motor	Can form camber during initial excavation, but not shaping.
17	Maintenance of earth haul roads	a. Grader with scarifier	Best machine for this work. Suitable for loosening and shaping top layer of earth road or runway.
		b. Dozer, tracked or wheeled	Should be used only if grader not available.
		c. Loader, track/wheel	
		d. Excavator	For excavation of culverts etc

Ser	Operation	Heavy Equipment	Remarks
		e. Backhoe	
		f. Scraper	Initial use to improve grades.
18	Digging battle trenches and support weapon trenches	a. Backhoe	
		b. Excavator	For larger trenches.
19	Digging field fortifications-shelters/com-mand posts/aid stations	a. Excavator	
		b. Backhoe	For smaller fortifications when excavator not available.
		c. Dozer, track/wheel	Only if excavator not available.
		d. Loader, track/wheel	
20	Digging vehicle emplacements	a. Excavator	
		b. Backhoe	When excavator not available.
		c. Dozer, tracked or wheeled	Used for vehicle emplace-ments when soil does not have to be removed.
		d. Loader, track/wheel	
21	Digging antitank ditches	a. Dozer, tracked	Best machine. Work in pairs.
		b. Excavator	More productive when working in pairs.
		c. Dozer, wheeled	Only to assist in berm placement.
		d. Loader,track/ wheel	
22	Digging field sanitation facilities	a. Backhoe	
		b. Excavator	

23	Excavating building construction site	a. Backhoe	For small shallow vertical excavation.
		b. Excavator	For deeper vertical excavations.
		c. Dozer, tracked	For large excavations without vertical embankments.
		d. Loader, wheeled or tracked	For loading excavated soil in haulage vehicles.
24	Loading material - debris, rubble, soil, rock and snow	a. Loader, wheeled or tracked	Primary loader of dump trucks.
		b. Excavator	
		c. Backhoe	
25	Lifting - Material lifting and handling tasks	a. Crane	Best for heavy and extended lifting.
		b. Excavator with backhoe bucket	
		c. Loader with forklift attachment	For loading containers and pallets.
26	Pile driving	Crane with pile driver attachment	

Fig 7A-1 Heavy Equipment and Heavy Equipment Tasks

CHAPTER 8

GENERATORS AND POWER DISTRIBUTION

GENERAL

1. The Canadian Forces have several varieties of generators in use for field operations. These generators range from 0.5 to 100 kw and their uses vary from supplying power to vehicle mounted command posts, to lighting static field camps. The general operating instructions, safety precautions and maintenance instructions for generator sets are covered in this chapter. For further instructions, see the specific operator manual and check the plates attached to the machine.

0.5 KILOWATT GENERATOR

2. The 0.5 kw generator is used to supply power to vehicle mounted command posts that have a maximum of two radios. It has the following specifications:

a. gasoline engine - 1½ hp;

b. fuel tank - 4.5 litres;

c. fuel consumption - 2.2 litres per hour;

d. generator - 0.5 kw, 28 volt DC; and

e. crankcase - one litre of SAE 30 (summer) or SAE 10 (winter).

5 KILOWATT GENERATOR

3. The 5 kw generator produces alternating current (AC) which can be used to supply power to a command post complex containing several radios and an internal lighting system. Normal equipment such as florescent lights, photocopiers and refrigerators can also draw power from this generator. It has the following specifications:

a. gasoline engine - 10 hp;
b. fuel tank - 20 litre jerry can or modified 200 litre drum;

c. fuel consumption - 6.5 litres per hour;

d. crankcase - 9 litres of SAE 30 (summer) or SAE 10 (winter); and

e. generator - 5 kw:

(1) volts - 120/240 volt one phase or 120/208 volt three phase,

(2) amperes - 52 amps at 120 volts, one phase; 26 amps at 240 volts one phase; 30/17.3 amps at 120/208 volts, three phase, three wire; and 30 amps at 120 volts three phase, four wire,

(3) kilowatts - 5 kw, and

(4) rpm - 3 600.

10 KILOWATT GENERATORS

Specification	**10 KW Generator**	
	Gasoline Engine	Deutz Diesel
Engine	10 hp gasoline	two-cycle, four-stroke direct injection diesel
Fuel tank	20 litre jerry can or a modified 200 litre drum;	45.5 litres
Fuel consumption	9 litres per hour	0.275 kg per kilowatt hour
Crankcase	9 litres of SAE 30 (summer) or	6 litres: a. -50 to -18°C

Specification	**10 KW Generator**	
	Gasoline Engine	Deutz Diesel
	SAE 10 (winter)	SAE 5W20 AP1/CC, SF, SE, b. -18 to 0°C SAE 10W20 AP1/CC, SF, SE, and c. 0 to 53°C 3-GP-304M Grade 30.
Volts	one phase 120/240 V and 120 V, and three phase 120/208 V	single phase two wire 120 V, single phase three wire 120/240 V , and three phase four wire 120/208 V.
Amperage	three phase, 34.7 amps per line, one phase 104 amps, and 52 amps on 240 V connection	104, 52 and 35 amps
Kilowatts	10 kw	10 kw
RPM	3600	1800
Phase	one or three phase.	one phase two wire 120 V, one phase three wire 120/240 V or three phase 120/208 V

Fig 8-1 Standard 10 kw Generator Specifications

4. Normally 10 kw generators are used to supply power to large field camps which contain lighting, refrigeration, electric heating systems, and communications, ADP and recreation facilities. They can be skid mounted or trailer mounted for ease of transport.

SAFETY PRECAUTIONS

5. **Safety Precautions.** The following safety precautions are common to all generators, but the operator shal refer to the operator's manual for detail unique to that model:

a. ensure the generator is properly grounded at all times;

b. locate a dry chemical fire extinguisher near the generator to combat fuel and electrical fires;

c. ensure that the generator has proper ventilation and exhaust gases are piped away from the working and living area;

d. shut down the generator and if possible cool prior to refuelling;

e. ensure the generator is as level as possible during operation;

f. do not smoke or use an open flame when servicing batteries because they produce a highly explosive gas;

g. remove all jewelry and metal items before working on electrical equipment;

h. wear ear protectors when operating a generator set;

j. rope off an area around the generator being serviced to protect other personnel;

k. use caution when removing the cap from a radiator that contains hot engine coolant. Rotate it slowly to reduce pressure;

m. do not co-locate material or equipment in the generator trailer as damage and electrical shortages can occur; and

n. leave all maintenance beyond operator maintenance to qualified technicians.

6. During wet and damp conditions, the generator can be dangerous. If a person becomes the victim of electrical shock, **SHUT DOWN** the generator before attempting first aid. If the work area is damp, use insulated materials or a wood platform to avoid serious shocks;

OPERATOR MAINTENANCE

7. The following operator maintenance procedures are common to all generators, but operators shall refer to the manufactuer's maintenance manual for details unique to that model:

a. inspect the generator for leaks, broken, loose or missing parts;

b. check fuel and add as required, ensure no water or dirt enters the fuel tank;

c. inspect and clean the fuel cap and tank screen as required;

d. inspect the fuel filter and sediment bowl at every fill up for accumulation of dirt and water;

e. check the oil level every eight hours, add oil to full mark only. **DO NOT OVERFILL**;

f. inspect and clean the breather relief valve;

g. inspect and clean the air cleaner;

h. inspect for proper grounding at both the grounding rod and ground terminal of the generator;

j. inspect the battery for loose cables, cracks and proper water levels; and

k. during operation, check all instruments and settings for security and proper operation, excessive noise, slowing down of the engine or a strange odor indicating a problem. **SHUT DOWN** and inspect the generator if a problem develops. If the problem cannot be resolved by the operator, contact a qualified technician.

8. The qualified technician shall:

a. adjust rheostat to obtain selected voltage. If problems occur, check for loose connections and adjust the carburetor;

b. if the percent load meter fluctuates, check for loose connections, then check that the applied load is within 500 watts (0.5 kw), and

c. proceed with appropriate repairs as required.

POWER DISTRIBUTION

9. Power distribution sets are available for field generator sets. The fuse breaker panel works much the same as the breaker panel in a home, allowing for guarded circuits and preventing the circuits from becoming overloaded which causes damage to the generator and components connected to the power source.

CHAPTER 9

RESOURCES

SECTION 1

INTRODUCTION

GENERAL

1. Engineer resources cover a wide range of equipment and materials which are sub-divided into engineer equipment, engineer stores, heavy equipment and defence stores. This chapter deals exclusively with those engineer stores that are used to complete field engineer tasks.

2. The availability and supply of different types of resources varies according to the area of operations. For instance, there is a scarcity of large timber in the sub-arctic area of Canada compared to heavily wooded areas in Northwest Europe. Due to logistic problems, it is often necessary to use less suitable or inferior materials that are found close at hand. For field engineering tasks, planners shall consider the use of local materials, even though this may require design adjustments.

3. This section discusses engineer resources in general, Section 2 deals with small scale logging operations, and Section 3 covers defence stores. Annex A contains tables on the mass of various materials and common Canadian timbers. The safe angle of repose and the bearing pressure of rock and soil is contained in Annex B.

RESOURCE CATEGORIES

4. **Engineer Resources.** Engineer resources is a generic term which includes anything required by engineer units to complete their tasks. The term includes engineer stores, equipment, heavy equipment, and defence stores. It also typically includes labour or manpower and transport integral to engineer units.

5. **Engineer Stores.** Engineer stores are either expendable or recoverable materials that are normally used in engineer tasks. Engineer stores include:

a. culverting;

b. expedient trackway;

c. building materials such as cement, lumber and hardware; and

d. road construction materials such as sand, gravel and asphalt.

6. **Engineer Equipment.** Engineer equipment is tools and implements used repeatedly in engineer tasks but not consumed. For example:

a. camouflet sets;

b. earth augers;

c. concrete breakers;

d. chain saws;

e. compressors, pumps and generators;

f. bridging; and

g. minelayers.

7. **Engineer Heavy Equipment.** Engineer heavy equipment is either self-propelled or towed machinery and attachments which are primarily used by engineers for horizontal and vertical construction. Heavy equipment capabilities and employment is discussed in Chapter 7.

8. **Defence Stores.** Defence stores are non-explosive materials used by all arms in defence works, including:

a. construction wire;

b. concertina and barbed wire;

c. pickets;

d. sandbags; and

e. corrugated galvanized iron (CGI).

NATURAL MATERIALS

9. **Rock**. Types of rock will vary from hard granite to softer materials such as shale and sandstone. For field engineering purposes, rock will be mainly used for tasks such as road and track maintenance or strengthening of entry and exit points for gap crossing sites. Sources shall be selected near work sites to reduce the hauling distance.

10. **Gravel and Sand**. Gravel and sand mixtures found in river beds or beaches make suitable aggregates for concrete but will require the addition of a binder before they are of much value for road construction. Gravel and sand found in natural deposits away from water usually have a clay content and provided that the right amount of water is present, make a good temporary road surface.

11. **Clay**. Pure clay is of little value to the field engineer as it becomes deformed when subjected to a constant load. Clay is useful as an improvised reservoir lining. Do not allow it to become dry and sun baked, or it will crack. These cracks will not close when the reservoirs are refilled.

12. **Turf.** Turf is the top few inches of soil in which grass is rooted. The roots hold the soil together and prevent erosion by wind and rain. Sod is a block of turf cut out of the ground that can be used for concealing excavated soil, or stabilizing embankments. When rolled up carefully, green side inwards, stacked and kept damp in a shady area, sod retains its colour and lives for a considerable period of time.

13. **Large Trees.** Large trees can be used in a variety of engineer tasks such as non-standard bridging, field machines and defensive positions.

14. **Saplings and Small Trees.** Saplings and small trees can be used for corduroy roads and improvised pickets for fencing and anchorages. They can also be used for the revetment of defensive positions, as well as concealing them.

SALVAGE MATERIALS

15. Salvage materials are items removed from demolished buildings and structures. Great care shall be taken, as removal may cause collapsing or detonate booby traps set by hostile forces.

16. Salvage bricks have many uses in field engineering. They are used as aprons for culverts, linings in sharp bends in drains, revetting and when crushed, they provide an excellent road repair material. When laying bricks as a revetment, lay them as sandbags against the soil at a slope of 4 to 1 with each course horizontal and with the vertical joints staggered. When paving, lay them in a level foundation of sand or dry earth and break the joint in all directions.

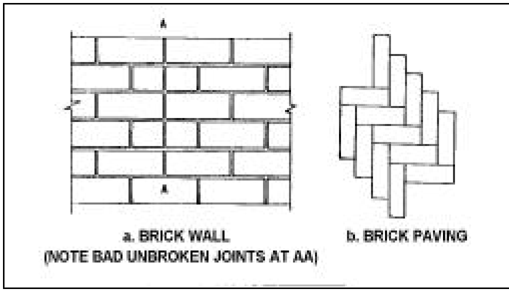


Fig 9-1-1 Use of Salvaged Bricks

17. **Timber.** Timber from wrecked buildings or structures is likely to be damaged. Inspect it carefully before putting it under a load. Check for nails especially when using a chain saw.

18. **Steel.** Recovered steel can be used in construction of improvised bridges and command posts.

19. **Corrugated Iron.** Corrugated iron is generally limited in quantities and a difficult resource to obtain. It shall be salvaged whenever possible.

SECTION 2

LOGGING OPERATIONS

SAFETY

1. Felling timber is the most hazardous part of logging, but other aspects of the job also require care and attention. Personnel will follow the chainsaw safety precautions detailed in Chapter 4.

2. The following precautions should be observed at all times:

   a. work in teams of two or more personnel and coordinate each other's work, between teams and within teams;

   b. maintain a safe distance between felling teams, and pause frequently to check and coordinate each other's progress;

   c. wear all protective clothing and equipment;

   d. select a safe line of retreat from the tree and physically check the route for obstructions such as deadfall;

   e. before making any cuts in a tree, study it carefully for lean, obstructions to the path of fall, loose branches, and the rolling effect of the trunk as it breaks away from the stump;

   f. before trimming a limb from a fallen tree, check that the action will not cause the trunk to roll towards you; and

   g. ever leave a tree partially cut.

3. Always bear in mind that in spite of careful planning the tree may not fall in the desired direction. Plan accordingly.

PREPARATION FOR FELLING

4. **The Lean of the Tree.** If a tree has a lean of not more than five (5) degrees, as evenly distributed branches, and is not being pushed by a strong breeze, it can usually be felled in any direction. Big trees that have

excessive lean or an unbalanced pattern of branches can seldom be fallen in the direction opposite the lean without the use of an aid such as blocks and tackle. However, by use of correct techniques, a tree in these circumstances can be felled as much as 45° either side of its natural lean.

5. **Clearing the Working Space**. Clear brush and small saplings adjacent to the tree to allow plenty of working space and remove low hanging branches.

FELLING TREES

6. **The Scarf (Notch).** The scarf (notch) is the V-shaped cut made in the tree on the side it is to fall. To aid in keeping this cut accurate, draw it with chalk or charcoal on the tree. It should be from 300 mm to 450 mm above ground level unless some obstruction. For example, a large rock, makes this impossible. The notch shall penetrate from one-third to half-way into the tree, depending on the centre of gravity. For a tree with a distinct lean that is being felled in the direction of the lean, a wedge penetrating one-third of the tree is sufficient. Cut to form an angle of about 45°. When cutting a large tree using an axe, the wedge can be formed by cutting two notches and then joining them as shown in Fig 9-2-1.

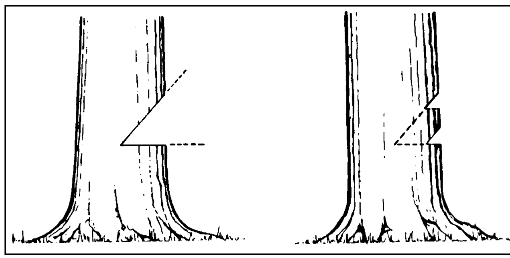


Fig 9-2-1 Scarf (notch) cut

7. **Making the Back Cut.** The back cut is the felling cut and it is made on the side directly opposite the wedge. It should be horizontal and approximately 50 mm above the floor of the wedge as shown in Fig 9-2-2. The back cut should penetrate the tree until about 50 to 80 mm of holding wood is left. This uncut wood is known as the hinge and serves to guide the tree as it falls. The hinge should never be less than 30 mm thick. If after making the back cut, the tree

is still balancing, it should be tipped by driving timber wedges into the back cut. Trees with a diameter larger than the length of the chain-saw guide bar can be felled by consecutive cuts as shown in Fig 9-2-3.

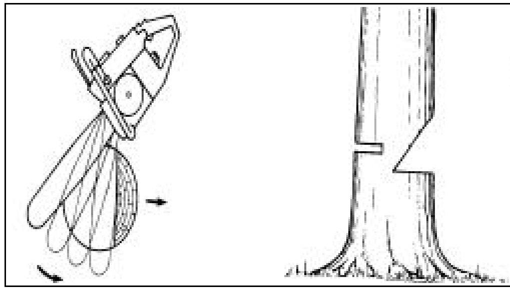


Fig 9-2-2 Back Cut

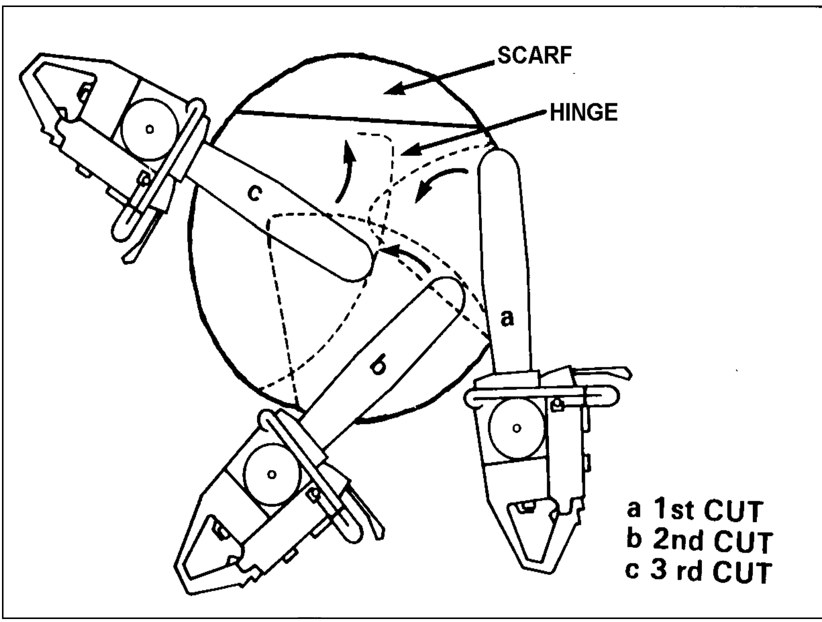


Fig 9-2-3 Consecutive Cutting iwth a Chainsaw

8. **Altering the Direction of Fall.** When a tree leans slightly in a direction different from that which it is required to fall, the direction of fall can be altered to a certain extent by one of the following methods:

a. **Holding a Corner**. Holding a corner involves leaving more hinge wood on the side opposite to which the tree leans when making the back cut. This acts as a hold back and twists the tree away from the direction in which it leans.

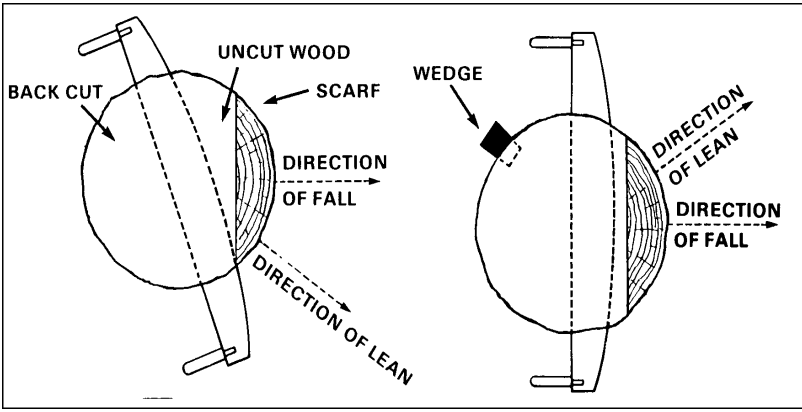


Fig 9-2-4 Holding a Corner and Wedging

b. **Wedging**. One or more timber wedges can be driven into the back cut on the leaning side in order to tip the tree into an upright position from which it can be made to fall in the desired direction.

9. **Felling Against the Lean.** Felling against the lean can be achieved providing the lean is not excessive. The back cut is made first and timber wedges are inserted before the saw blade becomes jammed. Wedging and sawing are continued until the tree is vertical. Once in a vertical position, the scarf (notch) is cut. The back cut is then completed and wedging is increased until the tree falls.

10. **Handling Hung-up Trees**. When working in thickly timbered areas it is sometimes impossible to prevent a cut tree from lodging in a standing one. The safest method of dealing with this, is to use a vehicle winch cable to pull the tree clear. Alternatively, if the tree is lightly lodged, cutting it loose from its stump and prying the butt to the ground may cause the tree to fall. A risky but sometimes unavoidable procedure is to fell the tree in which the first one is hung-up. It is difficult to judge the stresses involved, or the way the two trees will then fall, and this shall only be attempted by experienced tree fellers.

PREPARING THE LOG

11. After the tree has been felled, there are normally three preparatory actions that are carried out before the log is removed from the felling site: trimming, logging-up and de-barking.

12. **Trimming.** The removal of the limbs is known as trimming. Limbs are cut through from the bottom side and as close as possible to the trunk.

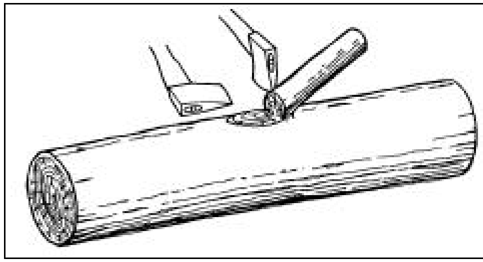


Fig 9-2-5 Trimming

13. **Logging-Up.** Logging up is the process of cutting the fallen tree to its required length.

14. **De-barking**. De-barking is the process of removing the bark to expose the solid timber beneath. On trees with a thick bark, this can be done by cutting a line with the chainsaw or axe along the tree trunk after it has been trimmed. The bark can then be removed by knocking it away with the back of an axe or adze, and then peeled away with the blade.

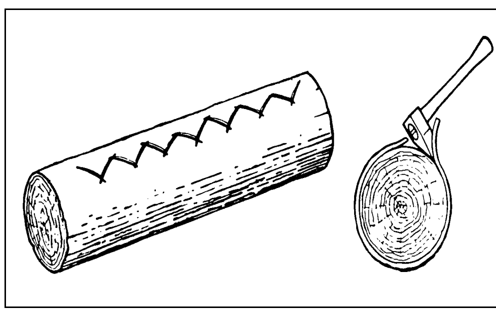


Fig 9-2-6 De-barking

SECTION 3

DEFENCE STORES

GENERAL

1. Defence stores are issued primarily to construct the field defences covered in B-GL-320-007/FT-001. Some details on the use of sandbags, and the cutting and bending of CGI (corrugated galvanized iron)are given in this section as both may be used in many other field engineer tasks.

2. **Sandbags.** Service sandbags are made of hessian or polyethelene and measure 825 mm X 250 mm. They are issued in bales of 1000 weighing approximately 210 kg. Sandbags are used to make repairs to trenches, to completely revet trenches, to reinforce buildings or to build blast walls.

3. **Sandbag Walls.** A sandbag wall will not stand with a vertical face; the wall requires a slope of 4 to 1. Sandbag walls will last longer if they are filled with a mixture of cement and sand at a ratio of 10 parts sand to one part cement. Examples of sandbag walls are seen in Fig 9-3-1and Fig 9-3-2. When building sandbag walls, remember the following points:

   a. sandbags are turned inside-out so that the seams are on the inside.

   b. sandbags are to be three-quarters full and the necks tied;

   c. sandbags are laid in horizontal layers. The first course is laid as headers at right angles to the length of the wall. The second course is laid as stretchers parallel to the wall. Subsequent layers are laid alternately as headers and stretchers. The wall is always finished with headers;

   d. joints in adjacent layers are staggered. This will correctly bond the wall;

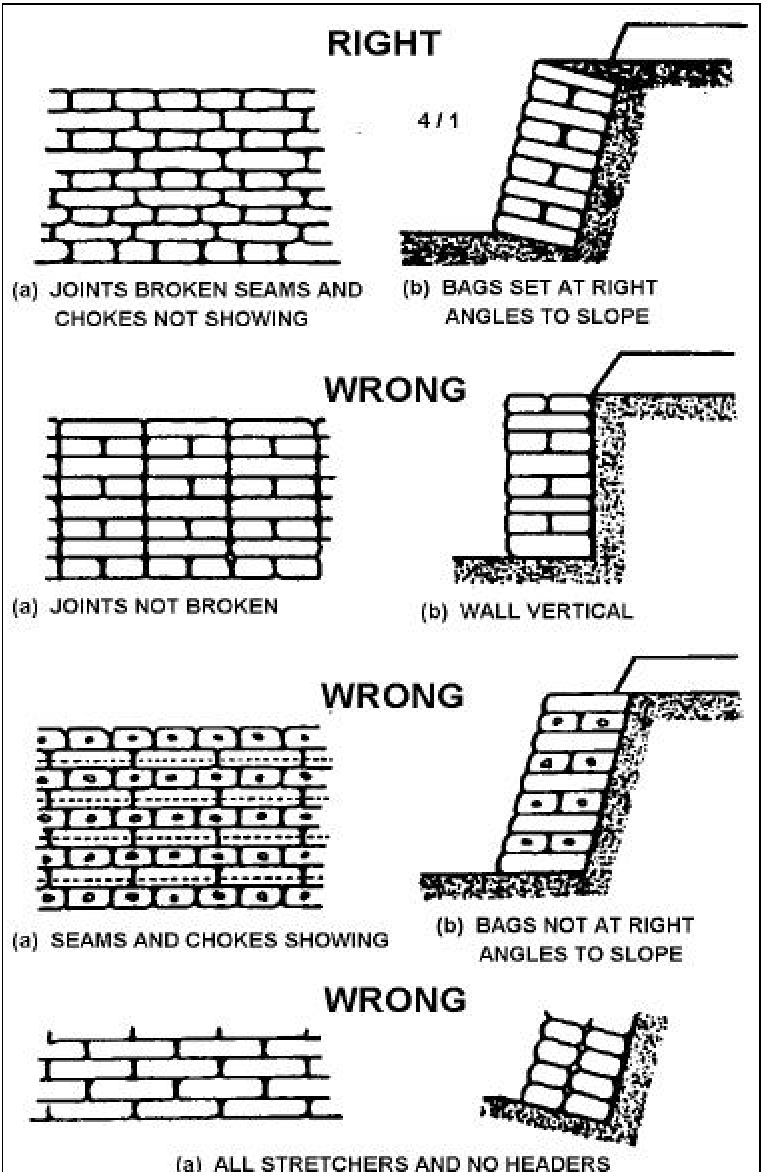


Fig 9-3-1 Examples of Correct Sandbag Wall Construction and Typical Mcistakes

e. because sandbags tend to burst at the seams and necks they are laid so that neither neck or seams are in the outer face of the wall. All corners are tucked in as each bag is laid;

f. after each bag is laid it should be beaten into a standard size and shape with a pick helve; and

g. **Turning a Corner**. Turning a corner involves partially filled sandbags (usually 3/4 filled). The method of turning a corner is shown at Fig 9-3-2.

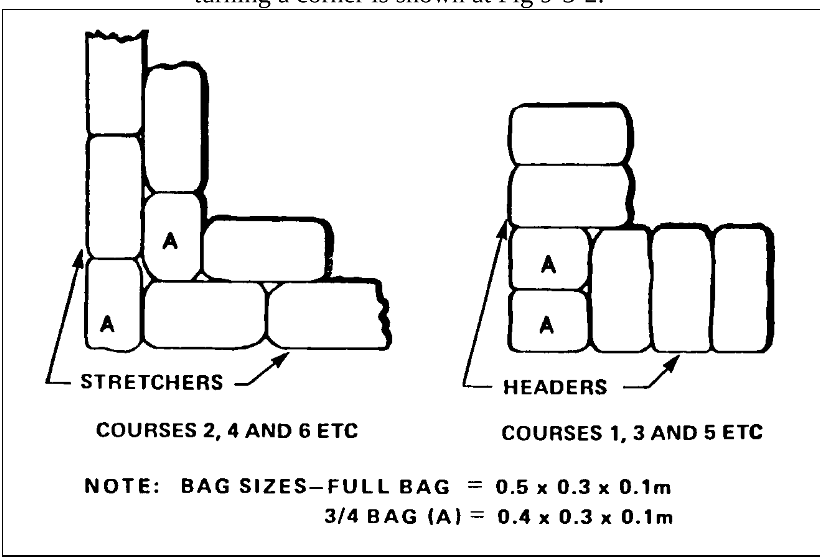


Fig 9-3-2 Turning a Corner

4. **Orgnization of a Sandbag Party**. A party of five soldiers plus the necessary carrying party can fill and lay 60 sandbags in one hour. The organization for building a sandbag revetment is based on the following:

a. one person filling sandbags;

b. two others holding them open and tying the necks as they are filled;

c. two people placing the sandbags at the wall; and

d. a carrying party moving in between.

FREE STANDING WALL DESIGN

5. **Free Standing Walls.** The designs for free standing walls that may provide protection against blast at entrances to shelters, vehicle pits or aircraft bays are shown in Fig 9-3-3. If the wall is more than 1.5 m high, it is better to use one of the designs at (b) or (c) in Fig 9-3-3 rather than making it entirely of sandbags as in Fig 9-3-3 (a).

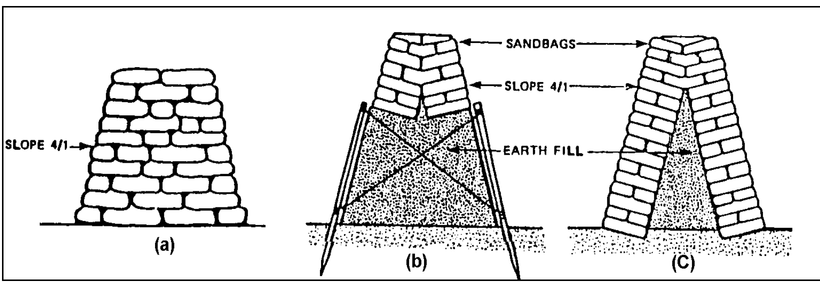


Fig 9-3-3 Sandbag Walls

CORRUGATED GALVANIZED IRON

6. **Cutting CGI.** CGI can be quickly and easily cut in the field by the following method (Fig 9-3-4):

a. anchor two strands of 14 SWG wire about 1.80 m long securely to a picket in the ground and secure the other end to a stick or pick helve;

b. lay the CGI over the wire at the position to be cut and as close to the anchor picket as possible. The edge of the corrugations of the sheet are turned towards the ground;

c. stand on the sheet facing away from the anchor picket with the feet close to the line of the cut and pull the wire upwards, as vertical as possible, using the stick held in the crutch of the arms; and

d. as the wire cuts through the sheet move the feet back along the line of the cut. Do not jerk the wire but apply a steady pull

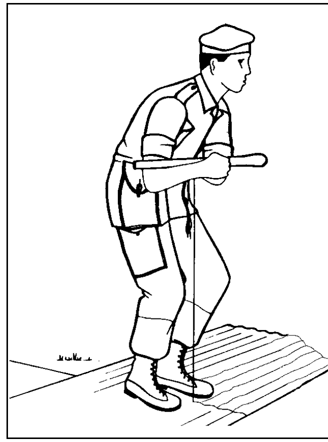


Fig 6-3-4 Cutting Corrugated Iron

7. **Bending CGI.** CGI can be bent across the corrugations as follows (Fig 9-3-5):

a. mark the sheet on both edges and lay an angle iron picket under the sheet along the line to be bent;

b. stand on the sheet to keep it in position and hammer on the corrugations along the picket edge, until a crease appears on the surface of the sheet;

c. reverse the sheet and lay the angle iron picket along the crease mark; and

d. stand on the angle iron picket and raise the end of the sheet to the proper bend. It is easier for two men to do this job. This method will produce a sharp bend that will fit around corners of trenches.

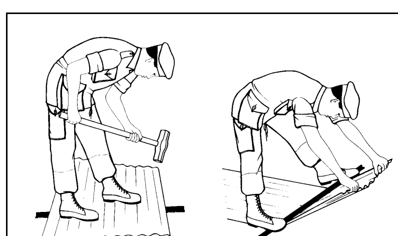


Fig 9-3-5 Bending Corrugated Iron

8. **Fastening CGI.** CGI can be fastened in several ways (Fig 9-3-6):

a. using nails with lead or rubber washers, to fasten to a timber frame for small building repairs;

b. wiring together onto timber or struts;

c. windless back when revetting fire trenches; and

d. in the case of a buried observation post, setting them into position and backfilling soil so that the pressure holds them in place against the framework.

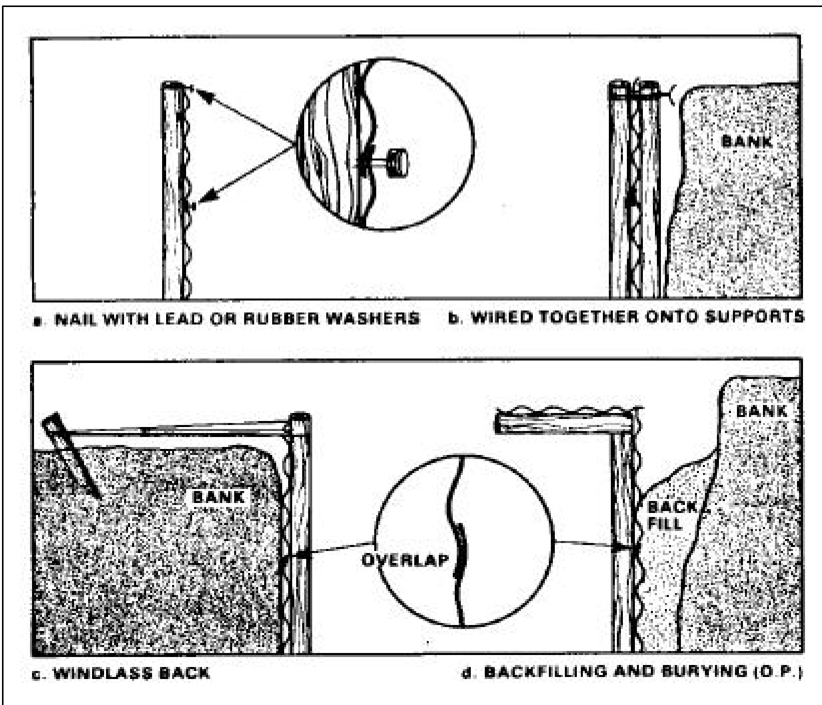


Fig 9-3-6 Methods of Fastening Corrugated Iron

ANNEX A

MASS OF SOME COMMONLY USED RESOURCES

Material	Unit Or Volume	Mass
Blue metal	m^3	2 t
Bricks common	1000	4 t
Cast iron	m^3	7 t
Cast steel	m^3	8 t
Cement	1 bag or $0.02m^3$	40 kg
Cement	25 bags	1 t
CGI (1.8 m)	1 sheet	7.5 kg
Concrete	m^3	2.5 t
Dog spikes	100	50 kg
Earth	m^3	2 t
Fencing wire	Coil (1000 m)	50 kg
Oils (all types)	200 l (drum)m^3	200 kg
Sand, beach, dry	m^3	2 t
Sand, beach, wet	m^3	2.3 t
Sand, river, dry	m^3	1.3 t
Sand, river, wet	m^3	1.5 t
Railway sleepers(Tie)	1	75 kg
Timber iron bark	m^3	1.5 t
Hardwoods	m^3	1.1 t
Soft woods	m^3	650 kg
Water, fresh	1 l	1 kg

Fig 9A-1 Mass of Commonly used Resources

STEEL 'I' BEAMS

Size - Depth X Width		Mass (kg/m)
Metric (mm)	**Imperial (in)**	
610 x 190	24 x 7½	149
560 x 178	22 x 7	112
508 x 165	20 x 6½	97
457 x 152	18 x 6	82
406 x 203	16 x 8	112
406 x 152	16 x 6	74
80 x 152	5 x 6	67
356 x 140	14 x 5½	60
330 x 127	13 x 5	52
305 x 203	12 x 8	97
305 x 127	12 x 5	45
254 x 203	10 x 8	104
254 x 203	10 x 8	82
254 x 114	10 x 4½	37
229 x 178	9 x 7	74
229 x 178	9 x 7	31
203 x 152	8 x 6	52
203 x 102	8 x 4	27
178 x 89	7 x 3½	22
152 x 127	6 x 5	37
152 x 76	6 x 3	18
127 x 64	5 x 2½	13
102 x 76	4 x 3	15
102 x 44	4 x 2	7

Fig 9A-2 Mass of Steel "**I**" Beams

SAWN HARDWOOD

Size -Depth X Width		Mass (kg/m)
Metric (mm)	**Imperial (in)**	
38 x 25	1½ x 1	1.0
50 x 15	2 x ½	0.8
50 x 25	2 x 1	1.4
75 x 15	3 x ½	1.25
75 x 38	3 x 1½	3.8
75 x 50	3 x 2	4.2
75 x 75	3 x 3	6.3
100 x 38	4 x 1½	4.2
100 x 50	4 x 2	5.6
100 x 75	4 x 3	8.4
100 x 100	4 x 4	11.2
125 x 38	5 x 1½	5.3
125 x 50	5 x 2	7.0
125 x 75	5 x 3	10.5
150 x 25	6 x 1	4.2
150 x 38	6 x 1½	6.4
175 x 38	7 x 1½	7.4
175 x 75	7 x 3	14.7
200 x 38	8 x 1½	8.5
200 x 75	8 x 3	16.8
250 x 38	1 x 1	10.6
250 x 75	1 x 3	21.0
300x 38	12 x 1½	12.7
300x 75	1 x 3	25.2
Scaffold planks:		
225 x 32	9 x 1¼	8.0
Note: Assumed mass of 1120 kg per cubic metre		

Fig 9A-3 Mass of Sawn Hardwood

SAWN SOFTWOOD

Size - Depth X Width		Mass (kg/m)
Metric (mm)	Imperial (in)	
38 x 25	1½ x 1	0.6
50 x 25	2 x 1	0.8
50 x 38	2 x 1½	1.2
75 x 38	3 x 1½	1.8
75 x 50	3 x 2	2.4
75 x 75	3 x 3	3.6
100 x 38	4 x 1½	2.4
100 x 50	4 x 2	3.2
100 x 75	4 x 3	4.8
100 x -100	4 x 4	6.4
150 x 25	6 x 1	2.4
150 x 50	6 x 2	4.8
175 x 38	7 x 1½	4.3
175 x 50	7 x 2	5.6
175 x 75	7 x 3	8.4
200 x 38	8 x 1½	4.8
200 x 50	8 x 2	6.4
200 x 75	8 x 3	9.6
250 x 50	1 0 x 2	8.0
250 x 75	10 x 3	12.0
300 x 50	12 x 2	9.6
300 x 75	12 x 3	14.0
Scaffold planks:		
225 x 38	9 x 1½	5.5
225 x 50	9 x 2	7.2
225 x 63	9 x 2½	9.0
Note: Assumed mass of 650 kg per cubic metre		

Fig 9A-4 Mass of Sawn Softwood (Pine)

ANNEX B

PHYSICAL CHARACTERISTICS OF ROCK AND SOIL

Type Of Ground	**Density (t/m^3)**	**Safe Angle Of Repose (degrees)**	**Safe Bearing Pressure (kgf/cm^2)**
(b)	(c)	(d)	(e)
Rock:			
Granite[1]	2.7	9.065e+17	20
Shale and Sandstone	2.6		8 - 12
Non-cohesive Soil:			
Well-graded sand gravel[2]	1.9		3 - 4
Poorly graded sand gravel	1.8		2 - 3
Poorly graded sand	1.7		1 - 2
Loose uniform sand	1.6		0.5 - 1
Cohesive Soil:			
Stiff sandy clay and shale[3]	1.9		2 - 3
Firm sandy clay	1.8		1 - 2
Soft clay and silt with organic matter	1.6		0.25 - 0.5

Notes:

1. Allow for faults, cracks and flaking.
2. Use lower figure for uncompacted material or fill.
3. Much affected by water content; use lower figure for wet or undrained soil.

Fig 9B-1 Physical Characteristics of Rock and Soil

CHAPTER 10

MOVEMENT BY HAND AND SIMPLE MECHANICAL AIDS

SECTION 1

MOVEMENT BY HAND

GENERAL

1. The most common way of moving loads over a short distance during the completion of field engineering tasks is by lifting and carrying, either as an individual or as a group. Back injuries can occur when individuals lift heavy weights incorrectly and carrying parties risk accidents unless properly controlled. It is essential that personnel be made aware of the correct procedures for lifting and carrying loads detailed herein.

2. This chapter also describes some improvised mechanical aids, and outlines the safety precautions that must be observed.

INDIVIDUAL EFFORT

3. A human physical effort can be applied in four different ways: pulling, pushing, towing and lifting. In all cases, the maximum effect is obtained with the least risk of injuries when the back is kept straight and the legs do as much work as possible. For example, when picking up a filled sandbag, stand close to it with the feet about shoulder width apart. Then bend the knees, while at the same time letting the body incline slightly forward from the hips, grasp the bag, and raise it by steadily straightening the knees.

4. If a sandbag has to be carried an appreciable distance, it is best to carry it on a shoulder. Here again the legs can help the arms. Initial upward movement is given to the load by gently bending the knees and straightening them sharply, the arms are used to guide the load into position. Remember to always keep the back straight.

5. A filled sandbag weighs 20 to 22 kg. With a little practice, the average person should have no difficulty in picking up and carrying away a conveniently shaped weight of up to 30 kg. Given assistance in getting the

load onto his shoulders, he should be able to carry 40 kg, for example, a bag of cement.

CARRYING PARTIES

6. Where the load is either too heavy or too bulky to be carried by one person, a carrying party should be organized and a leader detailed to supervise the work. For a long load, such as a spar or length of pipe that can be easily grasped, the party should be lined up on one side of the load and the load carried on the shoulders.

7. If the load is too heavy for the number of personnel that can get a good grip on it or it is so awkwardly shaped that a firm hold is impossible, carrying bars should be inserted under, or through the load, or through slings supporting it. For instance, a roll of concertina, although only 13 kg, is an awkward one-man load, yet two rolls can be easily carried by two soldiers walking one behind the other, with the load on two steel pickets.

CARRYING PARTY PROCEDURES

8. Before a carrying task commences, the group must understand that they must concentrate on the job so that each individual reacts promptly to every word of command. Only then will the load be evenly distributed and carried with the minimum of effort and risk.

9. **Preliminary Procedures.** A leader is detailed for each task and is not to take part in the lift if the number of carriers exceeds eight. The leader, having ascertained what the load is, where it has to be taken, and any restrictions on the route, is responsible for:

a. making sure that there are sufficient personnel to carry the load;

b. obtaining carrying bars, slings, improvised shoulder pads, gloves or improvised hand protection as necessary;

c. reconnoitering the route and selecting the best path in order to avoid sudden changes in slope, sharp corners and projections which might catch the load;

d. sizing the party and dividing it evenly around the load (smaller personnel in front); and

e. thoroughly briefing the carrying party.

10. **Lifting the Load.** The commands are "HANDS ON", "PREPARE TO LIFT" and "LIFT". On the command "HANDS ON" the carriers bend down and take a firm hold on the load or the carrying bar. On the command "PREPARE TO LIFT" the carriers take up a proper lifting position. On the command "LIFT", they straighten up, steadily lifting the load. Lifting the load onto the shoulders should be done in three stages: to arm's length, to the chest and finally onto the shoulders. For the first two stages, the carrying party face inwards while during the third they turn to face forward.

11. **Lowering.** The commands are "PREPARE TO LOWER", and "LOWER". Lowering from the shoulders should be done in two stages. On the command "LOWER", the weight is taken from the shoulders and held in the hands at shoulder level. It is then lowered to the ground. All movements are carried out smoothly and gently. If the load is being moved, the first word of command is "CHECK", so that all members of the carrying party stop at the same time before preparing to lower.

12. **Resting.** During long carrying tasks, rest may be required. The position of carriers may be changed during rest periods to reduce fatigue.

13. **Towing and Hauling.** For larger or more awkward loads, it maybe more convenient for the party to haul the loads using cordage. For efficient work the following points shall be observed:

a. a thick rope is better than a thin one. A 32 mm diameter rope is best and a 16 mm rope is about the smallest that the average person can get a firm grip on;

b. the party shall be spaced equally along the rope on alternate sides, with the shorter carriers nearer to the load;

c. to optimize their tractive (pulling) forces, soldiers are to keep their legs, body and head in one straight line, letting their legs do the work using their arms simply as links between their body and the rope; and

d. the party must work and move together on the commands of the leader.

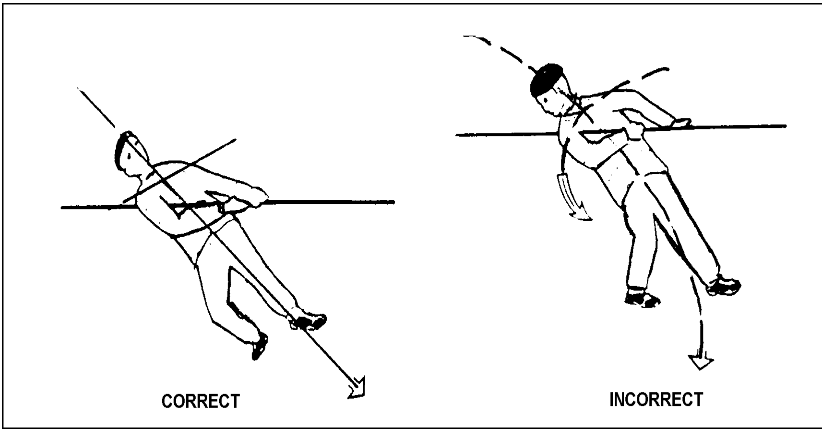


Fig 10-1-1 Right and Wrong Way of Heaving on a Rope

LABOUR CONSTANTS

14. If the ground surface is reasonably good and soldiers can exert their full power on the load, the number of soldiers required to lift or move a weight can be estimated using the following guide:

a. in small parties up to four, each can, for short periods only:

(1) push or pull horizontally with a force of 35 kg;

(2) pull downwards on rope (maximum three persons) with a force of 45 kg;

(3) lift 55 kg; and

(4) lift and carry 45 kg;

b. in large parties, there are factors which reduce the work that each individual can do. Each soldier can:

(1) lift and carry 25 to 40 kg;

(2) apply a tractive force of 20 to 25 kg on a tow rope; or

(3) exert continuous pressure of 7 to 10 kg on the bar of a capstan or handle of a winch.

SECTION 2

SIMPLE MECHANICAL AIDS

GENERAL

1. Humans have always used their intelligence to invent mechanical aids to increase their strength. This section describes several simple aids which can be easily improvised and outlines the safety precautions that shall be observed when using them.

SAFETY PRECAUTIONS

2. The biggest danger in moving heavy weights with mechanical aids is that the load may get out of control. The following precautions shall be observed:

a. the working party shall always be on the safe side of the load when working on a slope. Loads are hauled, not pushed, uphill;

b. be careful not to trip over the projecting rollers;

c. remove as many lashings or projections as possible;

d. on gentle slopes have two personnel with chocks walk on both sides ready to wedge if necessary; and

e. use preventer tackles on steep slopes, the running end of the hauling rope shall be taken twice around a holdfast picket. Should the load start to get out of control, the rope can be pulled tight to stop or slow the load.

LEVERS

3. The lever is a simple mechanical aid which is used to gain mechanical advantage when lifting (levering) objects. The point about which the lever rotates is called the fulcrum. The distance from the fulcrum to the points of application of the power and the weight are called the lever and counter-lever respectively. A lever may be used in one of three ways:

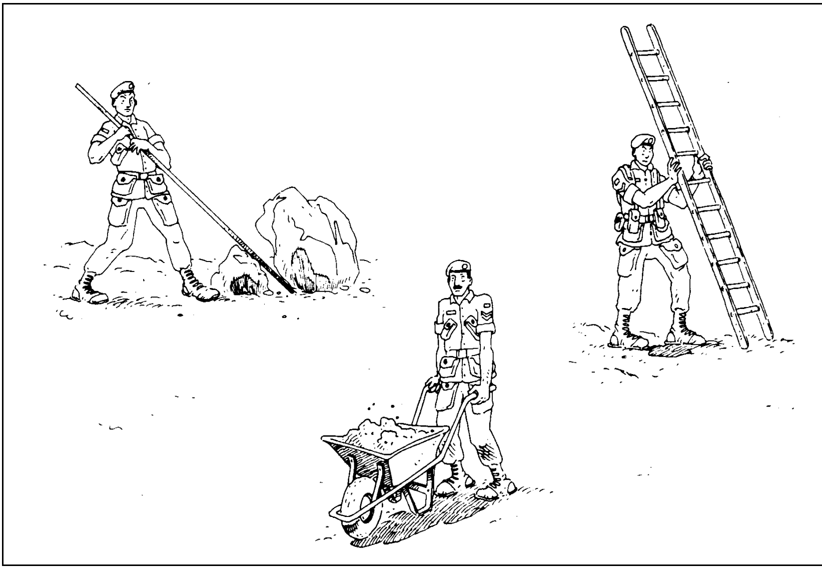


Fig 10-2-1 Examples of Levers

a. with the fulcrum between the weight and the power, as in the case of levering a rock;

b. with the weight between the fulcrum and the power, as in the case of a wheel barrow; and

c. with the power between the fulcrum and the weight, as in raising a ladder or scaffolding pipe.

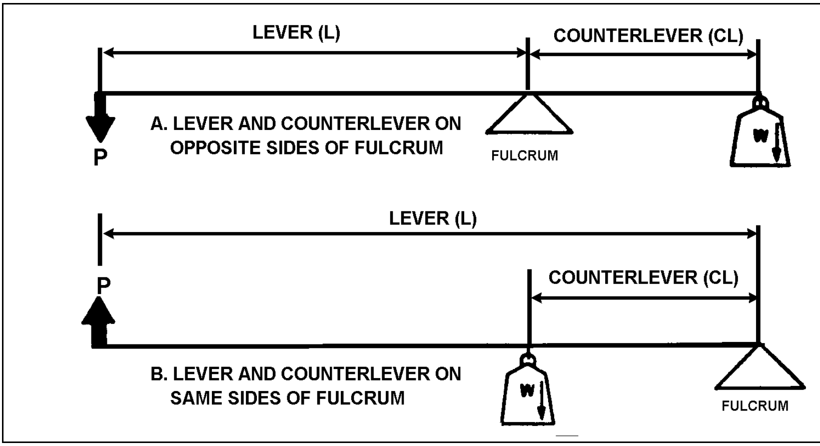


Fig 10-2-2 Levers

4. The crowbar is a commonly used lever and the carpenter's hammer employs the principle of a lever to draw nails. The cant hook (Peavy) (Chapter 3) is a special lever for rolling and turning logs.

5. The mechanical advantage of any lever is determined by the formula:

Mechanical advantage = $\frac{L}{C}$	Where L = the length of the lever, and C = the length of the counter lever

6. The power required to lift a given load is determined by the formula:

$P = \frac{W \times C}{L}$	Where P = power required W = weight C = length of the counter lever L = length of the lever

ROLLERS

7. Rollers can be used as an aid to moving heavy weights in a horizontal direction, or up and down slight slopes. They give no mechanical

advantage, but reduce the resistance to motion (friction). Rollers can be fixed or moveable.

8. **Moveable Rollers.** Moveable rollers are mainly used for moving heavy and bulky loads over fairly level ground. They may be improvised from steel bar, piping or hardwood logs. Provided that there is no slipping, the load travels twice as fast as the rollers over the ground and in the same direction, that is, at right angles to the axis of the rollers. If the load is required to travel in a curve, the rollers are laid out as shown in Fig 10-2-3. If the ground is soft, it may be necessary to lay down a plank path. Plenty of spare rollers should be available to feed in front of the load. Care is required to ensure that rollers projecting outside the edges of the load do not trip the working party.

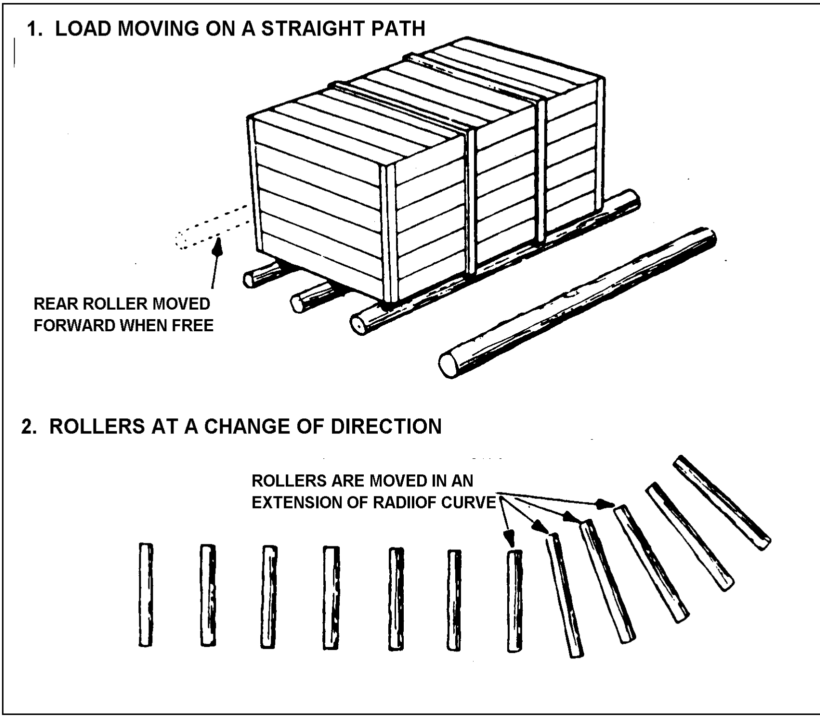


Fig 10-2-3 Movable Rollers

9. **Fixed Rollers.** Fixed rollers are special equipment such as those used in bridging operations.

PARBUCKLING AND WINDLASSING

10. **Parbuckling.** Parbuckling is a method of hauling a load up a steep slope such as a river bank. It can only be used on loads with a shape that will rotate fairly easily. The slope has to be free of prominent projections. If it is very rough an artificial slope can be made, for example, of two planks.

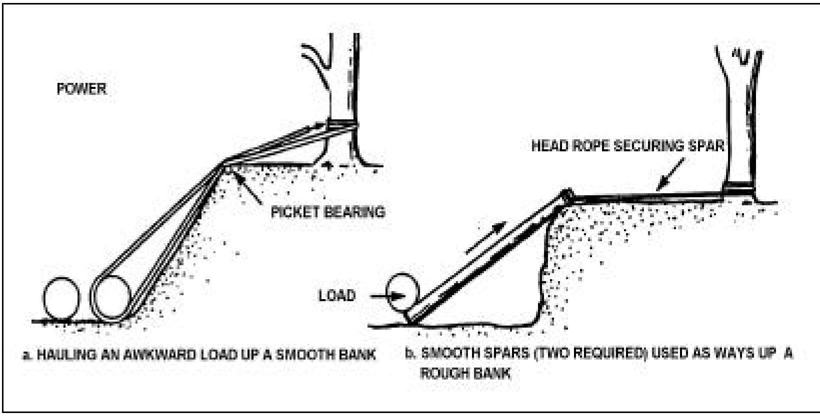


Fig 10-2-4 Parbuckling

11. **Spanish Windlass.** The spanish windlass can be used to move heavy loads over short distances (Fig 10-2-5). A rope is fastened to the weight to be moved and to an anchorage, and the windlass is erected on the line of the rope. The windlass consists of a vertical and horizontal spar with a bight of the rope taken around the horizontal spar. The weight is moved by rotating the windlass and the tow of the vertical spar moves towards the anchorage as the weight is pulled in. Care is required to ensure that:

a. the rope on both sides comes away from the vertical spar at the same level;

b. the windlass is set up exactly in line with the weight and anchorage; and

c. the vertical spar has a blunt end that will not dig in the ground.

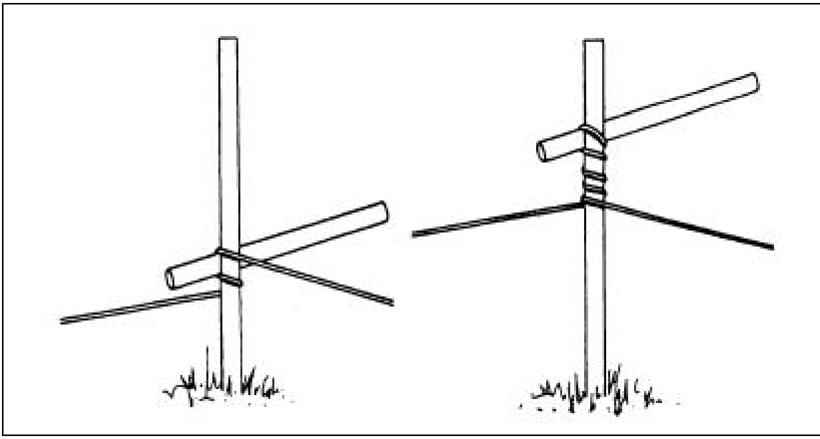


Fig 10-2-5   Spanish Windlass

CHAPTER 11

FIELD SURVEYING

SECTION 1

LEVELING

GENERAL

1. Before most tasks are started there is a requirement for dimensions of one type or another. Field surveying covers the various methods and equipment used to attain these measurements.

2. The basis of most field survey is geometry. Topics covered in this chapter are field leveling, measurement and geometry and their application to field engineering tasks.

LEVELLING

3. A line or a surface is said to be level when it is horizontal. Many field engineering tasks require surfaces that are more or less level and uprights that are roughly vertical.

4. **Principles**. There are two basic principles that allow horizontal and vertical lines to be established. First, a plumb-bob is drawn towards the centre of the earth by gravity, this gives a vertical line. Second, liquid will flow under the force of gravity until its surface is level, thus causing a horizontal line. These two principles form the basis of most levelling instruments, and govern their improvised construction. Field engineer levelling equipment ranges from boning rods to sophisticated optical devices.

NON-OPTICAL LEVELLING EQUIPMENT

5. The line level, and spirit level or carpenter level make use of the principle that the undisturbed surface of a liquid is level. If a bubble of air is placed in an enclosed glass container filled with liquid and the surface of the glass is parallel to the straight edge supporting it, the straight edge will be level when the bubble appears in the centre of the glass. The carpenter's level works on this principle.

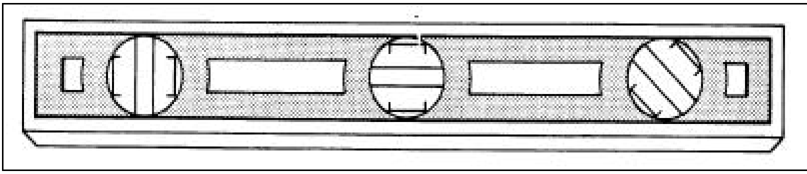


Fig 11-1-1 Carpenter's Level

6. **Field Level**. (Fig 11-1-2). The field level is a simple piece of equipment used by Field Engineers.

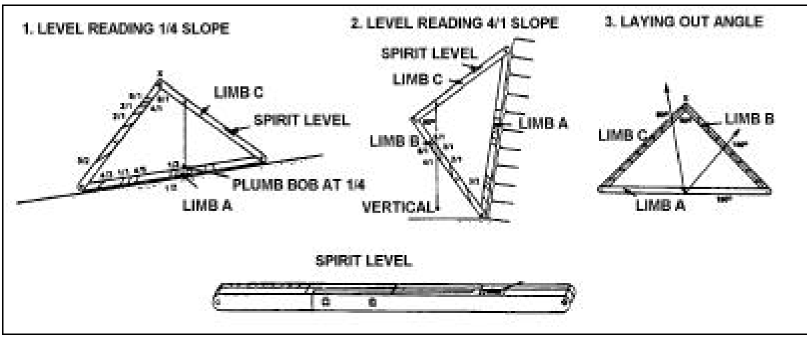


Fig 11-1-2 Field Levels

a. to measure a slope or gradient, fix the level with limb A along the slope or gradient and read off the figure cut by the plumb-bob line as shown in Fig 11-1-2 a and b.

b. to measure an angle, use as shown in Fig 11-1-2 c.

7. **Boning Rods**. (Fig 11-1-3). Boning rods are formed in the shape of a capital T. They are generally made of softwood 75 mm wide, 15 mm thick, and 900 mm high. Each consists of a long upright with a head fixed at right angles to the top. They come in sets of threes and of the same size. They are used in the following manner:

a. two pegs are driven flush with the surface on the line to be surveyed, as far apart as possible and made level with a straight edge or spirit level;

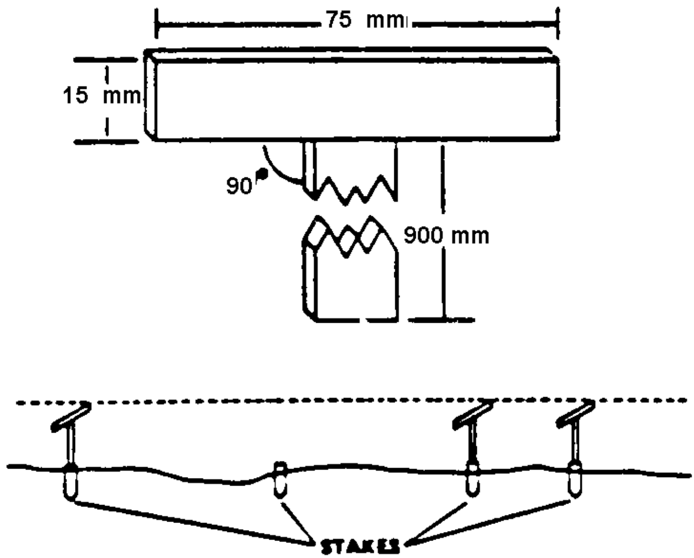


Fig 11-1-3 Boning Rods

b. a boning rod is then placed on each of the two pegs. Since the boning rods are identical in height, the line of site across the top edge of one to the top of the other will be level; and

c. at points farther along the line drive in other pegs. The third boning rod is held on each peg in turn and the difference in level is checked by sighting along the top of all three.

IMPROVISED LEVELLING DEVICES

8. A flat sided bottle filled with water, oil or some other liquid can be used as a level (Fig 11-1-4 a). To make a level, place a short length of tape about 5 mm across the end of the bottle as shown below, mark the tape with horizontal lines about 5 mm apart. Half fill the bottle with liquid and lay it on a roughly level surface, mark the liquid level on the line on the tape. Rotate the bottle 180 degrees and mark the liquid on the tape again, if the

mark is the same, the mark is the true horizontal position, if not the mid-point between the two marks is true horizontal. Clearly mark this point and you are ready to work.

9. **Length of Flexible Tubing**. A length of flexible tubing nearly filled with water can be used to level two points; for example batter boards on a construction site (Fig 11-1-4b). One end of the tubing is placed against the point from which the level is to be taken. Water is slowly trickled in, the other end of the tube is raised or lowered until the water stands to the brim at both ends. The two points are then level.

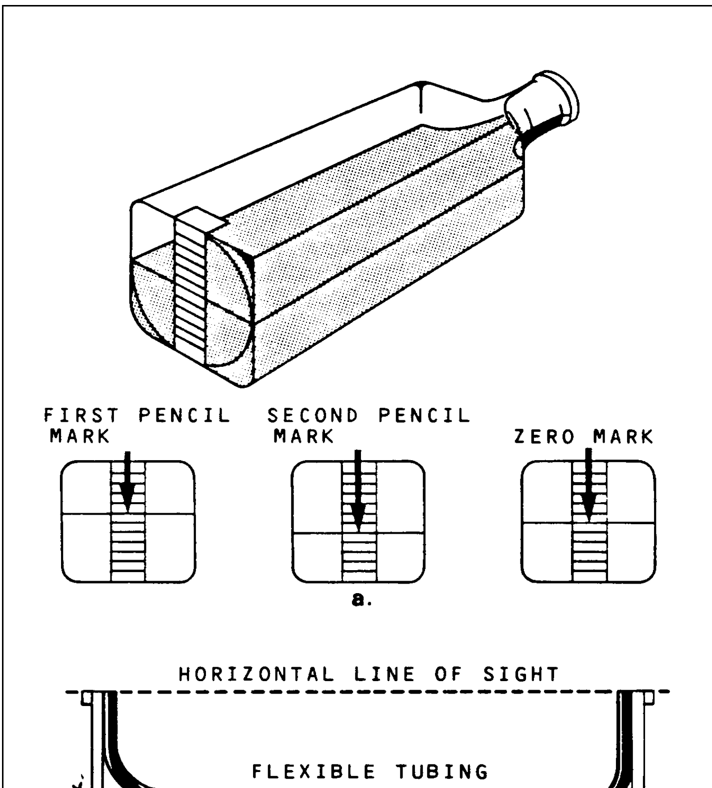


Fig 11-1-4 Improvised Levelling Devices

BATTER BOARDS

10. Batter boards are set up around building layout stakes and are located three or more metres outside the building lines. This enables form work or excavation to be done without disturbing the geometrical design. The boards are made of 50 mm x 100 mm stakes and 250 mm x 150 mm or wider ledgers. The ledgers are nailed to the stakes in a level position at a convenient working height above the foundation. The batter boards shall be approximately level with each other and the ledger boards must be large enough to extend well past each corner

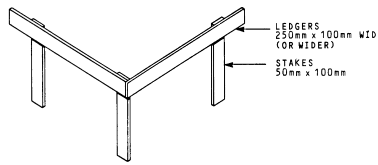


Fig 11-1-5 Batter Boards

11. Using lines and a plumb-bob, string the lines so that they pass directly over the layout stakes, this may be determined by using the plumb-bob. Mark the top of the ledger boards where the lines cross and make a shallow saw cut, pull the lines tight and fasten them to nails driven into the back of the ledger.

ABNEY HAND LEVEL

12. The abney hand level is a convenient pocket level used for measuring slopes either in gradients from 1:1 to 1:10 or in angles from 0 to 60 degrees. It is also used in cross ht. sections in road design, and determining heig

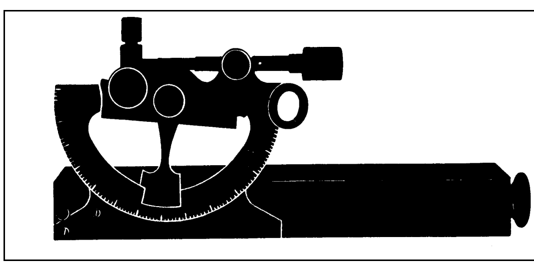


Fig 11-1-6 Abney Hand Level

13. Description. The level consists of a box with a slide, a sloping mirror and a horizontal wire. The slide must be fully extended before any readings can be taken.

a. **Mirror.** The mirror is a highly polished piece of steel, at an angle of 45° to the box, engraved with a horizontal line at its centre. This line and horizontal wire must lie on the line of sight through the axis of the level when measuring a slope. The function of the mirror is to reflect the image of the bubble to the observer's eye, through a hole in the top of the body.

b. **Vertical Arc**. On the side of the body is a vertical arc graduated in gradients and degrees on either side of a zero mark. Both depressions and elevations may be read to an accuracy of 10 minutes of a degree (3 mils).

c. **Bubble Tube**. The bubble tube is tilted about the centre of the vertical arc by a milled nut. The vernier arm is attached to the bubble tube axis and moves with the tube. To check the level, the index must be at 0° when the level is on a true horizontal surface. The bubble is bisected by the engraved line on the mirror. If any adjustments are required they are made by altering the capstan nuts at each end of the bubble tube.

14. **Method of Operation.**

a. The telescope is focused on the object so that it is intersected by the horizontal hair. The bubble image is then moved by adjusting the milled nut until it is intersected by the horizontal engraved line at the same time as the object is intersected by the horizontal hair. The required angle or gradient is then read off on the vertical arc against the index of the vernier arm.

b. To lay out a slope this procedure is reversed. The gradient or angle is set on the vertical arc and the level is tilted until the bubble is intersected by the line of the mirror. At this point the horizontal hair will be intersecting a point at the required gradient as measured from the observer's eye. The range pole has a sight vane on it at the same height as the observer's eye.

ENGINEER LEVELS

15. Where more precise levelling is required an engineers level is used. The levels in current use in the service today are Fuji, Geo Tech, and Nikon and Wild. These are capable of resolving differences in height and can also be used to measure horizontal distances. Each type of level comes with its own user handbook.

SECTION 2

MEASUREMENT

LINEAR MEASUREMENTS

1. **Length**. Standard metric units of linear measurement are millimetre (mm) or 1/1000 of a metre, metre (m) which is equivalent to 100 centimetres or 1/1000 of a kilometre, and kilometre (km) 1000 metres. Volume and area are derived from these linear units.

2. **Area**. Area is measured as length X width and is expressed as units squared: square millimetre (mm^2), square metre (m^2), square kilometre (km^2) or hectares (ha) (10,000 m^2).

3. **Volume**. Volume is measured as length X width X height and is expressed in cubic measurement: cubic metres (m^3), millilitres (ml), cubic centimeters (cc) and litres (l).

MEASURING SLOPES

4. Slope is defined as the measurement of the inclination of a surface in terms of rise over run. It can be expressed in degrees, or as a percentage or ratio. For example, a rise of one metre in ten metres could be written as ratio of 1 to 10 (1:10), or a percentage 10% or in degrees 6°.

5. Slopes can be measured by using a field level, boning rods, or an Abney hand level. Two types of slopes are shown in Fig 11-2-1 and Fig 11-2-2.

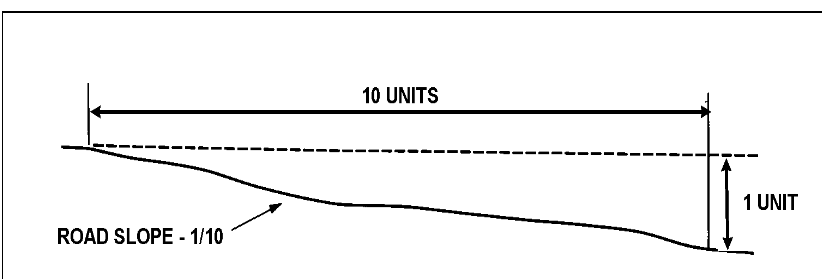


Fig 11-2-1 Gradient on a Road

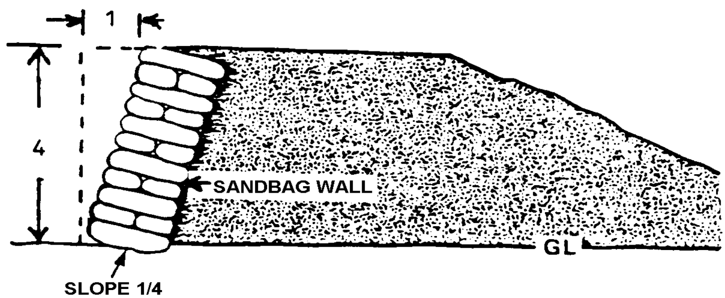


Fig 11-2-2 Slope of a Sand Bag Wall

6. **Field Level**. For short slopes where the surface is uneven the method shown in Figure 11-2-3 is suitable. The level is 1.2 m long and can be used in the folded position with the spirit level up.

Average slope = 1 : $\frac{1.2}{h}$	where:	h is the height from the ground to the level.

The same procedure can be used with the line level and a measured piece of string.

7. **Using Boning Rods**. For a long slope, where an average figure is required, boning rods can be used as shown in Fig 11-2-3:

a. set out two boning rods on the slope, with the distance between them determined by the ability to site over both;

b. hold the center or intermediate rod closest to whichever rod is convenient and where a straight sight can be made over all three rods;

c. place a straight edge on the intermediate rod and the next closest; and

d. read the slope with a field level and plumb-bob positioned on the straight edge resting on pegs that supported the boning rods.

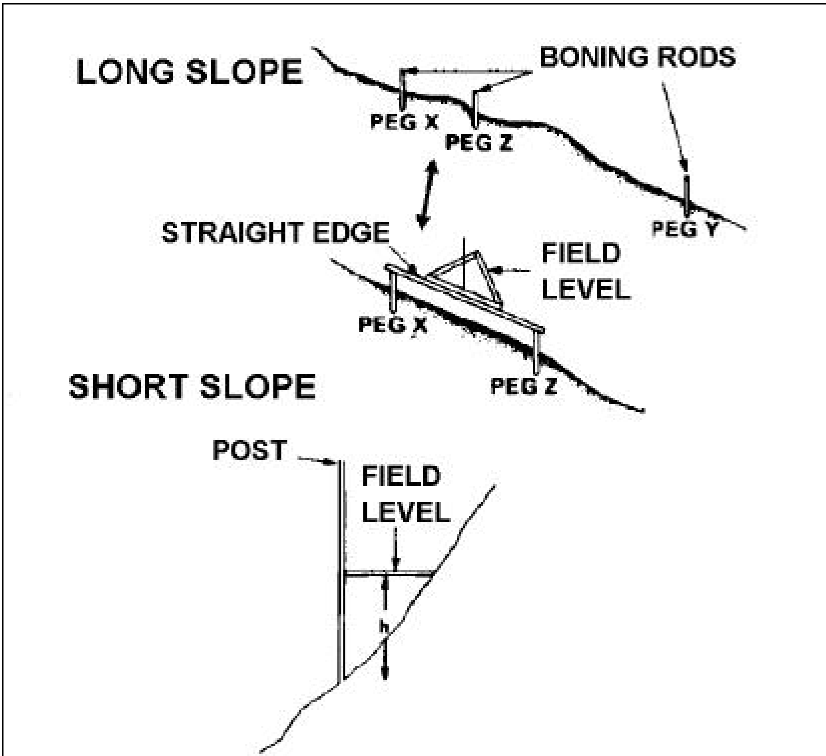


Fig 11-2-3 Measuring Slopes

SECTION 3

GEOMETRY

GEOMETRIC FIGURES

1. **Angles**. Angles are commonly used in field engineering for mine warfare, road survey, bridging and a number of other tasks. Angles are measured in degrees or mils, there being 360 degrees or 6400 mils in a complete circle.

2. **Triangles**. A triangle is an enclosed three-sided figure where the sum of the three interior angles equals 180 degrees (3200 mils). The area of a triangle is determined by multiplying the length of the base by the height and dividing by two (Fig 11-3-1).

$$A = \frac{b \times h}{2}$$

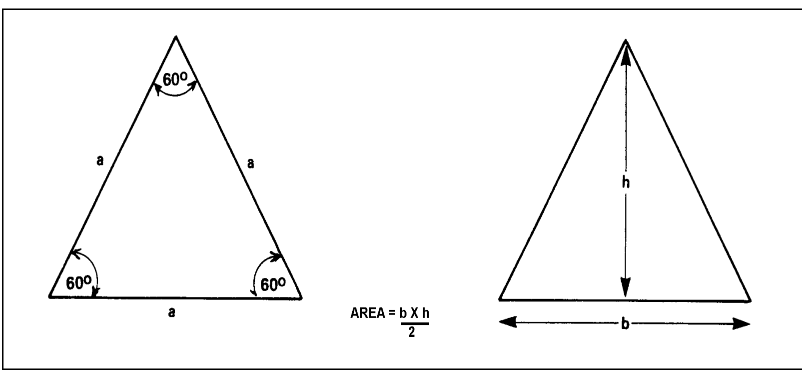


Fig 11-3-1 Triangles

3. **Parallelograms**. Parallelograms are four-sided figures in which the opposite sides are parallel. Rectangles and squares are also parallelograms. The area of a parallelogram is found by multiplying the length of one side by the perpendicular height of the other side. They have the following characteristics:

a. opposite sides are of equal length;

b. the four angles total 360 degrees (6400 mils); and

c. opposite angles are equal.

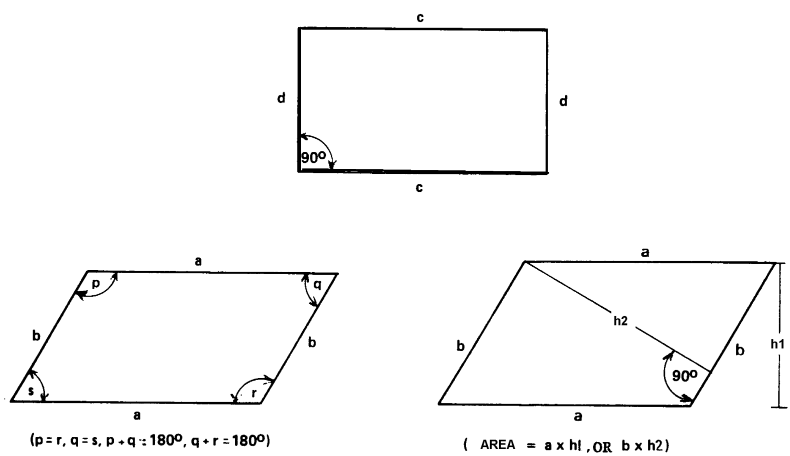


Fig 11-3-2 Parallelograms

4. **Trapezoids**. Trapezoids (Fig 11-3-3) are four-sided figures with one pair, but not both pairs of sides parallel. They have the following characteristics:

a. one pair of sides do not have equal angles;

b. all sides are not of equal length; and

c. the area of a trapezoid is found by multiplying the height by the average of the two parallel sides.

$$A = h \times \frac{(b1 + b2)}{2}$$

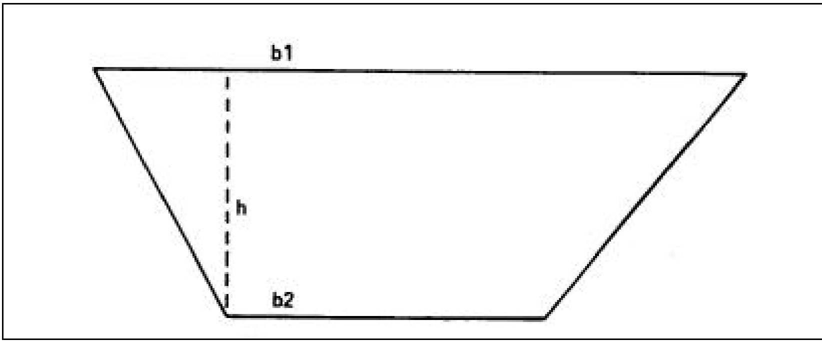


Fig 11-3-3   Trapezoid

5. **Circles**. A circle is bounded by a single line in which every point on the line is the same distance from the center. The length of this line is known as the circumference (c). The distance from the centre to the line is called the radius (r). A straight line drawn from one point on the line through the centre to a point opposite is called the diameter (d). is a value that represents the numerical relation between the circle's circumference and it's diameter; that value is 3.1416.

a. circumference (c).

$$c = 2\,r = \pi\,d$$

b. area (A).

$$A = r^2 = \frac{\pi\,d^2}{4} = \frac{c^2}{4\pi}$$

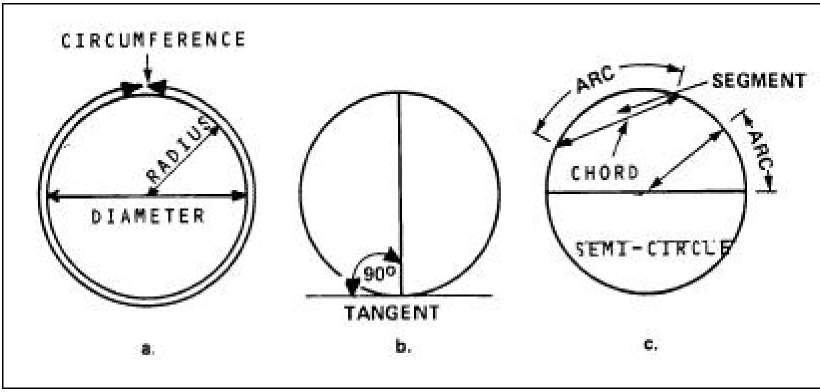


Fig 11-3-4   Parts of a Circle

c. **Example Problem**. Find the circumference and area of a circle with a +diameter of 15 mm.

(1) circumference. $c = \pi\ d = 3.1416 \times 15 = 47.124$ mm

(2) area. $A = \dfrac{c^2}{4\pi} = \dfrac{(47.124)^2}{4 \times 3.1416} = 176.72\ mm^2$

FIELD GEOMETRY

6. Field geometry is the application of the basic geometry discussed in the previous section. The equipment required is: a tape or string, wooden stakes and a hammer.

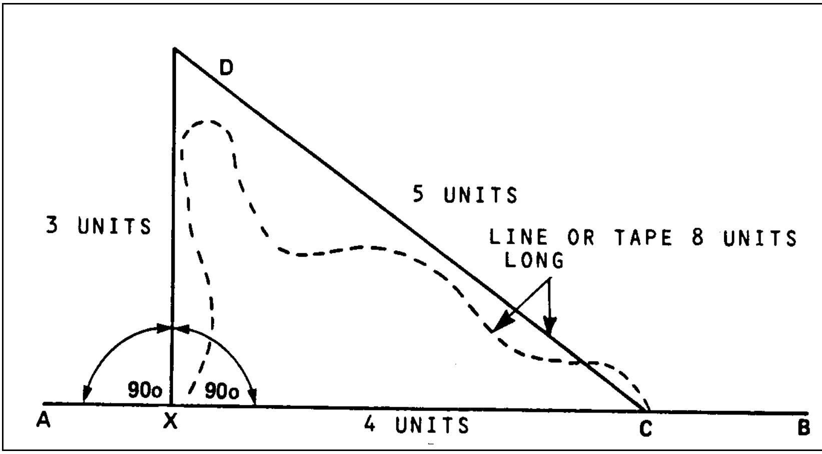


Fig 11-3-5 Setting Out a Right Angle

7. **To Set Out a Right Angle**:

a. lay out base tape AB and drive stake at point X;

b. mark a tape or string in three lengths: one of three units, one of four units and one of five units; and

c. place the ends of the string on the stake at X, run the tape four units along the base AB to establish point C. Loop the string over a stake at C. Pull the string taut and establish point D so that XD is three units and DC is five units long. The angle formed at X is a 90° angle.

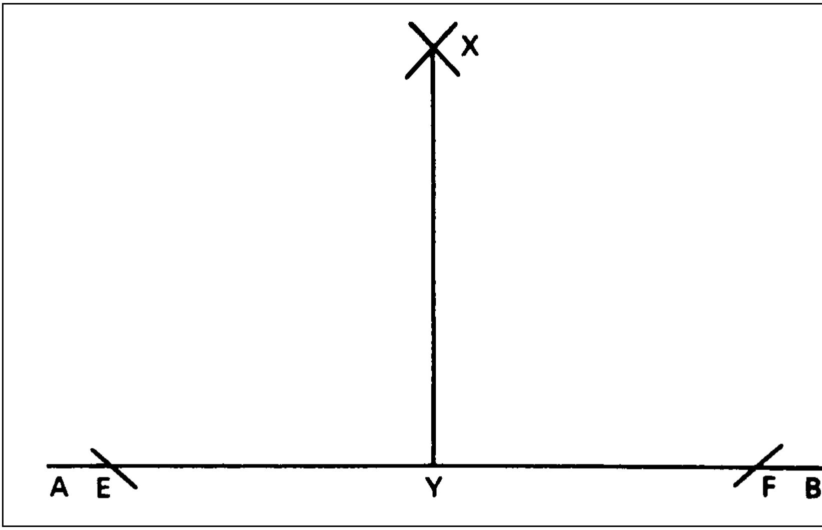


Fig 11-3-6 Setting Out a Right Angle Away from a Line

8. **To Set Out a Right Angle Away From a Line** (Fig 11-3-6), when AB is the given line and Y is the given point that the right angle to AB is required:

a. establish points E and F equal distances from Y along line AB;

b. take a string longer than line EF and find it's mid-point;

c. from points E and F extend the string so that mid-point X is established; and

d. angle XYB is a right angle.

9. **To Set Out 30^o and 60^o Angles to a Given Line** (Fig 11-3-7):

a. drive a peg at point X on line AB and at any convenient point along AB place a second peg C;

b. to pegs X and C attach the ends of a string which is twice the length of XC;

c. grip the centre point of the string, draw it taut and peg it at point D;

d. the angles at DXC, XCD and XDC will be 60°; and

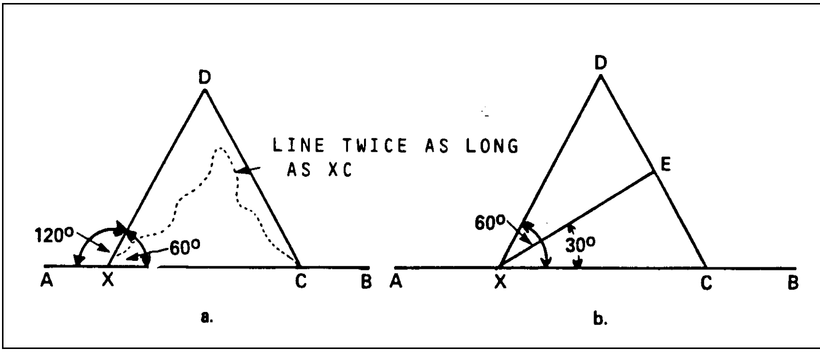


Fig 11-3-7 Constructing an Angle of 60°

e. by finding the centre along line DC, point E, and drawing line between X and E, a 30° angle is formed at angle EXC.

10. A **45° Angle** is normally found by bisecting an angle of 90°:

a. form a 90° angle DXC along line AB;

b. shorten the base by one unit. Draw a line from D to the shortened point on AB, point E. Connect D and E with a tape; and

c. find the centre point F of line DE and connect X and F. The angles formed at X to D and F, and X to F and E are 45° angles.

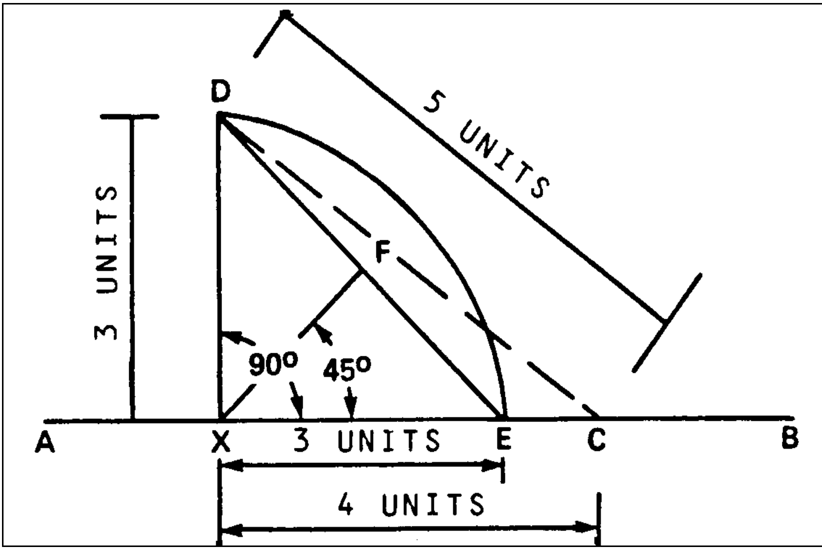


Fig 11-3-8 Constructing an Angle of 45°

11. **Bisecting Angles** (Fig 11-3-9 a):

a. hold one end of a length of string at 0 and mark points C and D so that lines OC and OD are equal in length and must be the same distance from OE;

b. at C and D take another length of string slightly longer then CD, scribe two arcs that intersect a point E;

c. join line OE; and

d. the triangles formed by COE and DOE will be equal, therefore angle COE equals angle DOE.

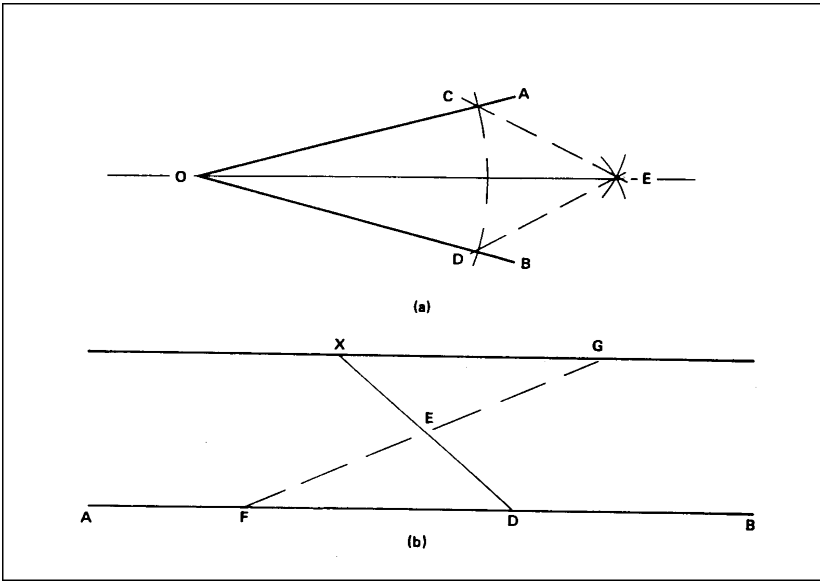


Fig 11-3-9 Bisecting Angles and Forming Parallel Lines

12. **To Form a Parallel Line** (Fig 11-3-9 b):

a. on a given line AB select a point D; run a line from point D to a point X where the parallel line is to be established (for greater accuracy the angle of ADX should be between 45 and 60^{o});

b. mark the centre of XD as point E;

c. select a second point F on AB and join F and E and extend the line to G so that EG = FE; and

d. XG will be parallel to AB.

MEASURING A GAP

13. It is often necessary to measure the distances between two points that are separated by a gap such as a river. Two methods of measuring using field geometery are described below. Stores required are string or tape, stakes and a hammer.

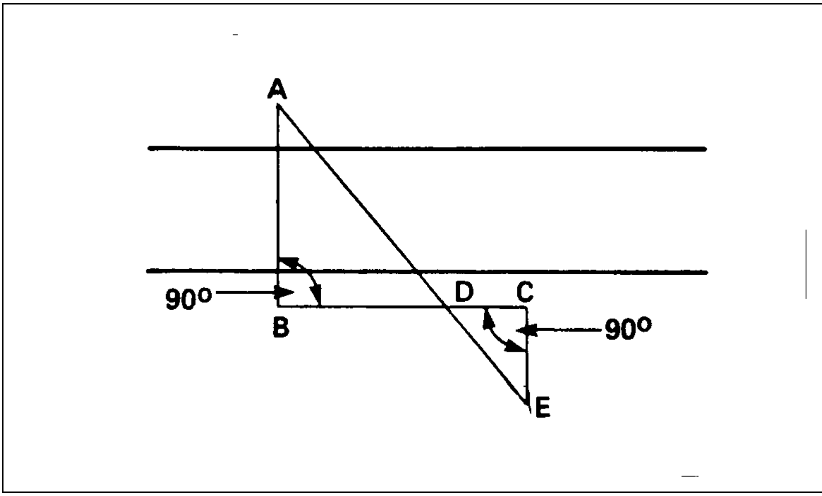


Fig 11-3-10 Measuring a Gap

14. **Method 1 - Using Proportional Right-Angled Triangles**, where AB is the distance to be measured (Fig 11-3-10):

a. place a stake at point B and, using a string, mark a line BC at right angles to line AB making line BC as long as practical;

b. choose a point D on BC so that the length of DC is a convenient proportion of the length of BD ie. 1/2, 1/3 or 1/4;

c. at C lay off CE at right angles to BC. Follow line CE to point E where A can be sited through point D, place a stake E;

d. the two triangles ABD and ECD are proportional and right angled and, because BD and DC are proportional to each other the other sides are also proportional so that AB and EC are in the same proportions; and

e. if BD is three times larger than DC then AB is three times larger than EC.

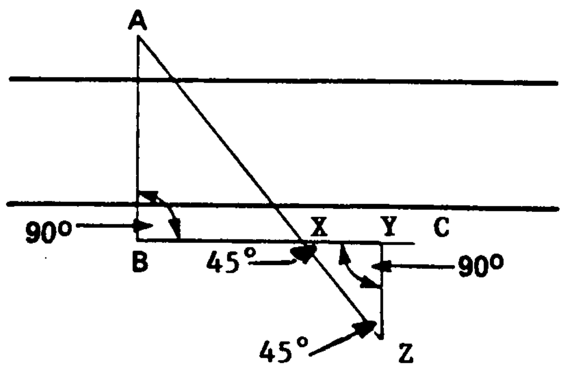


Fig 11-3-11 Measuring a Gap

15. **Method 2 - Using Proportional Right-Angled Triangles**. Where it is difficult to get a clear line of vision back from the near bank this method may be used. The method is only approximate and requires three personnel (Fig 11-3-11).

a. lay down a base tape BC at right angles to AB;

b. using the method illustrated in Fig 11-2-8 lay out triangle XYZ with the base XY parallel to the gap. The sides XY and YZ should be equal and as long as possible;

c. have one person hold the corners of the triangle XYZ keeping it taut. Persons X and Y walk down the base tape BC until person Z is able to line up X and A then halt is called; and

d. the angle formed by AXB will then be 45° degrees and BX will be equal to AB.

SECTION 4

HEIGHT, AREA AND VOLUME

CALCULATING HEIGHT

1. **Using a Known Reference**. The height of an object such as a tower or a cliff can be measured by using the shadows formed by the cliff and any convenient pole that can be measured. The ratio of the length of the cliff shadow to the pole shadow gives the ratio of the cliff height to the pole height.

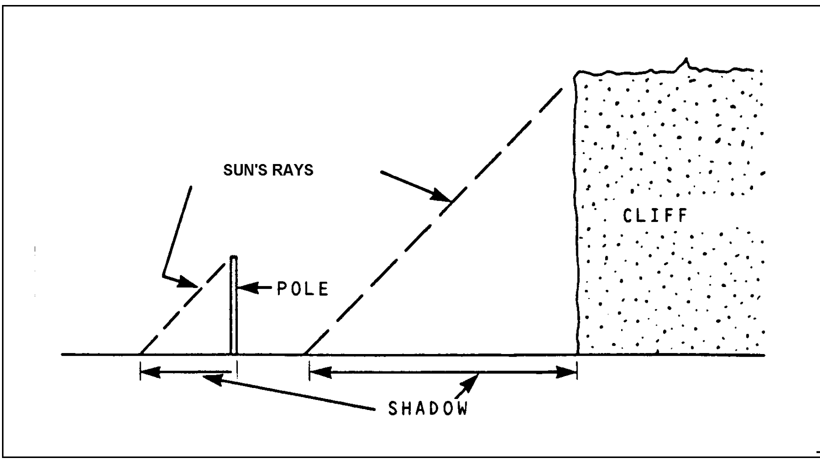


Fig 11-4-1 Establishing Height

2. **Using the Abney Hand Level**. The angle or gradient read on the Abney Hand Level can be correlated with the tables at Fig 11-4-2 and Fig 11-4-3 to produce the height of an object. Fig 11-4-2 lists gradients corresponding to applicable angles which would otherwise have to be interpolated from the vertical arc. Fig 11-4-3 gives values for vertical rise or fall per unit traversed horizontally. (Note: These two tables are designed for use with right-angled triangles).

Degrees	One in	Degrees	One in	Degrees	One in
1	57,0	10	5,6	26	2,0
2	28,6	12	4,7	28	1,88
3	19,0	14	4,0	30	1,73
4	14,3	16	3,4	32	1,6
5	11,4	18	3,0	34	1,43
6	9,5	20	2,7	36	1,37
7	8,1	22	2,4	38	1,23
8	7,1	24	2,2	45	1,00
9	6,3				

Fig 11-4-2 Gradients and Vertical Change of Certain Angles

Angle °	Rise or Fall	Angle °	Rise or Fall	Angle °	Rise or Fall
1	0,0175	16	0,2867	31	0,6009
2	0,0349	17	0,3057	32	0,6249
3	0,0524	18	0,3249	33	0,6494
4	0,0699	19	0,3443	34	0,6745
5	0,0875	20	0,3640	35	0,7002
6	0,1051	21	0,3839	36	0,7265
7	0,1228	22	0,4040	37	0,7536
8	0,1405	23	0,4245	38	0,7813
9	0,1584	24	0,4452	39	0,8098
10	0,1763	25	0,4663	40	0,8391
11	0,1944	26	0,4877	41	0,8693
12	0,2126	27	0,5095	42	0,9004
13	0,2309	28	0,5317	43	0,9325
14	0,2493	29	0,5543	44	0,9657
15	0,2679	30	0,5774	45	1,0

Fig 11-4-3 Gradients and Vertical Change of Certain Angles (Tangent Law)

3. It is essential that the horizontal distance from the observer to the object be measured or estimated. The height of the object above the observer's station = (angle to top of object) x (horizontal distance) + (height of observer's eye) (Method 1). When a building or object has sloping

ground from the observer to the foot of the building or object, an allowance must be made, (See Method 2).

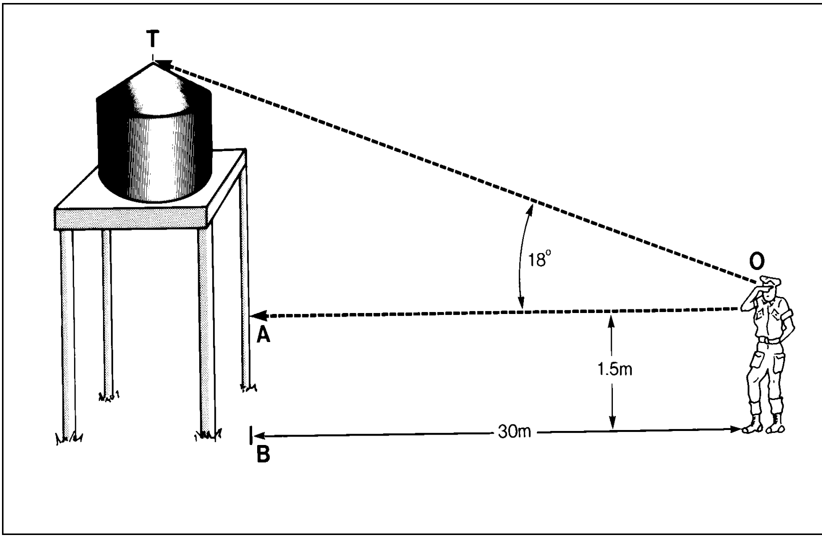


Fig 11-4-4 Finding Height of an Object (Method 1)

a. **Method 1.** The angle to top of tower is 18°, the height of the observer AB is 1.5 m and the distance from the observer O to the tower is 30 m.

(1) 18° expressed as a gradient (Fig 11-4-2) = 1 in 3 or 1/3 approximately or expressed as a decimal (Fig 11-4-3) = 0.3249.

(2) tower height TB = 1/3 x 30 + 1.5 m = 11.50 m; or TB = 30 x 0.3249 + 1.5 = 11.25 m.

b. **Method 2.** (Fig 11-4-5) The angle to the tower base is 10° above the observer's line of sight and to the top of the tower 36°. The distance from the observer to the tower base is 150 m.

(1) from Fig 11-4-2, angle to base (AB) = 0.1763 and angle to top (AT) = 0.7265.

(2) the distance (AB) from the observer's line of sight to the base = 0.1763 x 150 = 26.45 m.

(3) the distance (AT) from the observer to the tower top = 0.7265 x 150 m = 108.98 m.

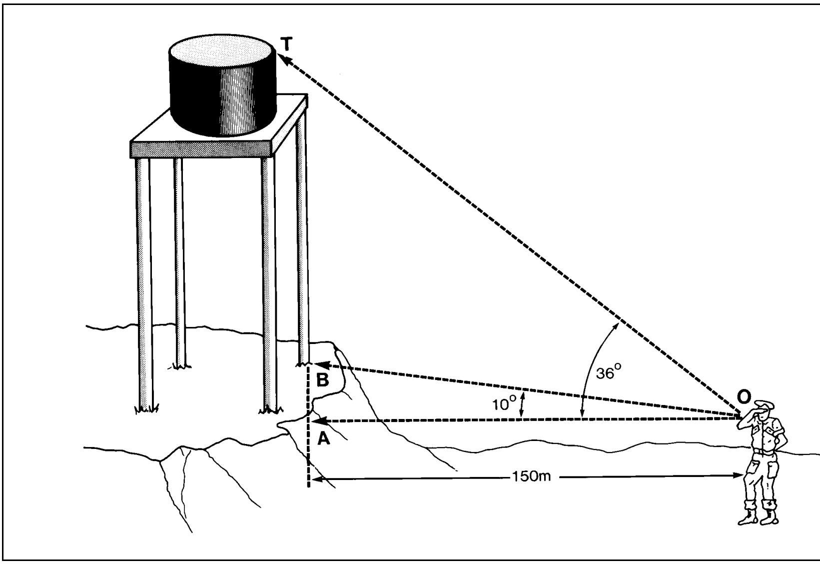


Fig 11-4-5 Finding Height of an Object (Method 2)

(4) height of tower = AT-AB=108.98m-26.45m= 82.53

c. In the case of small buildings on level ground, height may be obtained quickly as follows:

(1) set index to 45° elevation, or 1 in 1,

(2) stand back,

(3) look through telescope and put horizontal line on top of building,

(4) by moving towards and away from the building the engraved line will bisect the bubble, and

(5) measure distance from feet of observer to base of building and add observer's height to obtain the height of the building.

AREA OF IRREGULAR FIGURES

4. **Calculating the Area of Parts of a Circle**. Calculating the area of parts of a circle is generally obtained through a process of subtraction, for example:

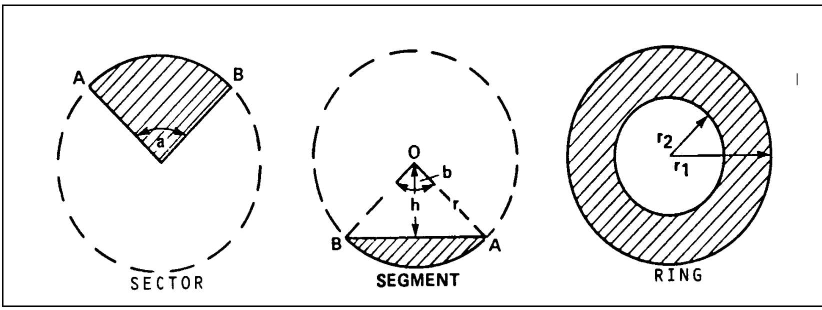


Fig 11-4-6 Areas of Parts of Circles

a. **Area of a Sector** subtending an angle "a" at the center. The area is proportional to the whole circle as angle "a" is to 360°.

$$A = \pi r^2 \times \frac{a}{360}$$

b. **Area of a Segment.** The area of a segment is the area of the sector OAB obtained above, less the area of the triangle AOB.

$$A = \pi r^2 \times \frac{a}{360} - \frac{AB \times h}{2}$$

c. **Area of Ring.** The area of a ring, for example the cross section of a pipe, can be calculated as the area of the outer circle minus the area of the inner circle.

$$A = \pi (R_1)^2 - \pi (R_2)^2 \quad \text{or } \pi (R_1^2 - R_2^2)$$

5. **Calculating the Area of a Polygon**. To calculate the area of an irregular figure bounded by a number of straight lines. Divide the figure, area ABCDE in Fig 11-4-7, into a series of triangles, and use the formula for calculating the area of triangles as described in Section 3.

6. When there are no clear lines of site across the figure, the answer can be obtained by calculating the area of the containing rectangle, AOPQ in Fig 11-4-7, and subtracting the unwanted areas.

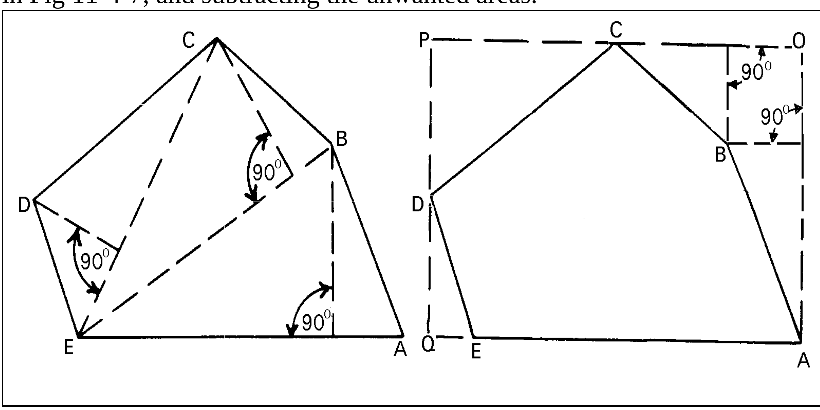


Fig 11-4-7 Calculating the Area of an Irregular Figure

7. Calculating the Volume of a Regular Solid.

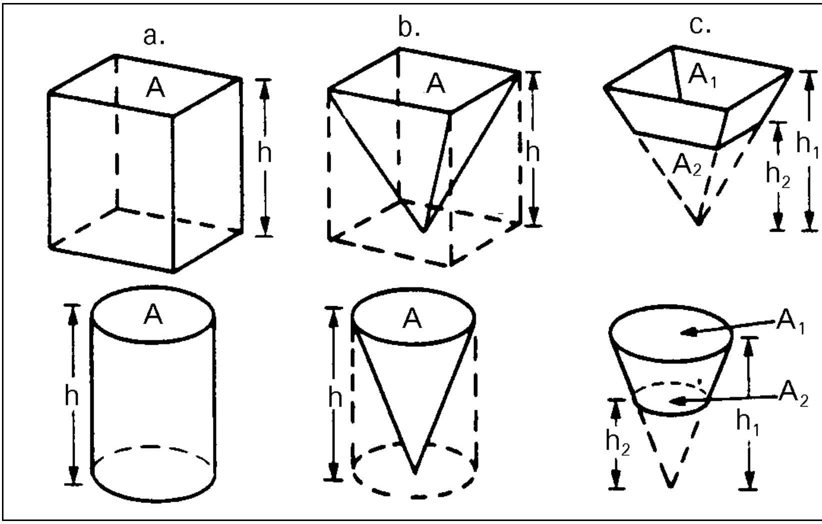


Fig 11-4-8 Volume of Regular Solids

a. The volume of a prism or cylinder is the area of the base X the height (h). (Fig 11-4-8a)

$$\text{Volume} = \pi r^2 \times h$$

b. The volume of a pyramid or cone is the area of the base multiplied by the height (h) then divided by three. (Fig 11-4-8b)

$$\text{Volume} = \frac{\pi r^2 \times h}{3}$$

c. To find the volume of a reservoir with sloping sides, the volume is that of the larger figure less the volume of the smaller (see Fig 11-4-8c).

$$\text{Volume} = \frac{(A_1 \times h_1)}{3} - \frac{(A_2 \times h_2)}{3}$$

NOTE: The values of h_1 and h_2 are calculated from the depth of the reservoir and the slope of the sides (Fig 11-4-8c).

ESTIMATING DISTANCE, AREA AND VOLUME

8. **Distance.** Each engineer shall be familiar with the following normal personal measurements:

   a. the normal length of a pace is about 750 mm;

   b. hand span is about 225 mm (small finger tip to thumb tip);

   c. palm width is about 100 mm (across the knuckles); and

   d. boot length is about 300 mm.

9. **Area.** Area can be judged by relating to familiar objects, ie:

   a. a soccer field is 1.8 ha; and

   b. a tennis court is 260 m^2.

10. **Volume.** Volume is more difficult to estimate:

   a. a 45 gallon drum holds 200 litres; and

   b. a one cubic metre tank holds 1000 litres.

CHAPTER 12

CONCRETE

SECTION 1

MATERIALS

CONCRETE GENERAL

1. Concrete is used for a great variety of military engineering tasks, from the construction of workshops, vehicle parks and roads in the rear area, to bridge abutments, and defence works in the forward areas. This chapter deals mainly with the smaller combat engineering tasks, where equipment may be limited to small tilting drum batch mixers, and transporting and placement would normally be done by hand.

2. Concrete can be either cast in situ or pre-cast. When cast in situ, that is, in its final position, it is retained in position until sufficiently hardened, either by timber or steel formwork, or by the sides of excavations when below ground level. Pre-cast concrete is small sections of concrete cast in moulds and subsequently incorporated in a project. It is often used for piles and small structural units which lend themselves to mass production.

MATERIALS

3. Concrete is formed by the chemical reaction which takes place when water is added to a mixture of dry cement and aggregate. Aggregate is the term used for sand and stone of various sizes that make up the bulk of the concrete. The chemical reaction induced in the cement powder by water generates a certain amount of heat and causes the cement paste that is initially formed, to change into a hard solid that binds the aggregate together.

4. The quality of concrete depends on the properties of the components used in the mixture and on the way it is handled, compacted, finished and cured. Care is necessary during all these operations to ensure the best results are achieved. To be of high quality, concrete:

a. contains the correct proportion of cement, aggregate and water;

b. is made with clean aggregate and water; and

c. contains no voids, but no concrete should be made without entrained air which produces a more durable concrete.

PROPERTIES OF COMPONENTS

5. **Cement**. The cement most commonly used is Portland cement. It is manufactured in five types which are referred to as type 10, 20, 30, 40 and 50.

a. Type 10 Normal - General Purpose;

b. Type 20 Moderate - Mild Sulphate;

c. Type 30 High Early Strength - Fast curing - one week or less;

d. Type 40 Low Heat Hydration - For large pours; and

e. Type 50 Sulphate Resisting.

If a type has an "A" designation, the cement contains entrained air. Type 10 is used for the majority of structures and for the majority of field engineering tasks. The other types have particular properties, such as high early strength and sulphate resistance.

6. **Initial Set**. Setting is the term used to describe the initial stiffening of the cement paste during the period in which it loses its plasticity and becomes firm. The rate of setting is affected by the chemical composition (type), cement fineness, and the water content and temperature. A mix with a high water content takes longer to set, and high temperatures cause more rapid setting.

7. **Placing and Curing**. Hardening is the process which follows after setting is complete. The term har- dening is used to describe the development of strength. This takes place quickly during the con- crete's early life and then at a diminishing rate more or less indefinitely. Rapid hardening concrete (Type 30) has a high early strength (that is during the first seven days) although after twenty-eight days it has the same strength as normal concrete. The rate of hardening is important because it affects the length of time formwork must be left in position and the time that must elapse before the structure can be loaded. The relationship between concrete strength and age is shown above.

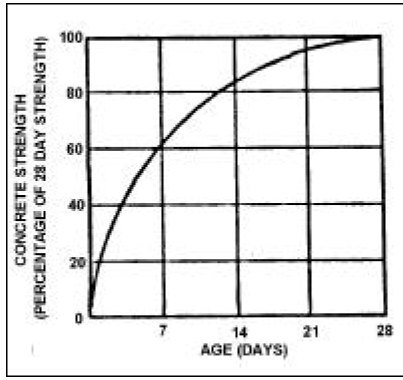


Fig 12-1-1 Strength and Age Relationship for Standard Concrete

8. Special procedures for curing concrete in hot and cold weather are as follows:

a. hot weather -

(1) cool materials with water,

(2) use ice water in mix,

(3) provide shade,

(4) work during the cool part of day, and

(5) keep from drying for a minimum of three days, preferably seven days by using a water spray, ponding, covering or curing agents.

b. cold weather -

(1) keep from freezing,

(2) use hot water,

(3) work during the warm part of day,

(4) provide heated shelter, and

(5) keep moist as for hot weather.

9. **Aggregate**. Concrete aggregates consist of clean, hard, durable particles which are strong enough to withstand the loads imposed on the concrete. A good aggregate consists of a combination of sands, and gravels or crushed rock. All aggregates require good grading and cleanliness.

10. **Grading**. Unless concrete can be compacted so that there are no voids between the particles, the concrete will not develop its maximum strength. To eliminate voids, it is necessary to have particles of varying sizes in the correct proportion. Grading is tested by the use of sieves of standard sizes. Material that passes through a 5 mm mesh sieve is generally classified as fine aggregate or sand, and the material retained by the sieve as course aggregate.

11. **Cleanliness**. It is important that the aggregate is clean. The presence of dirt, clay or organic matter may prevent the adhesion of the cement to the aggregate and slow the setting and hardening process. A simple test to determine the cleanliness of fine aggregate is to rub a sample through the hands; if there is more than a slight

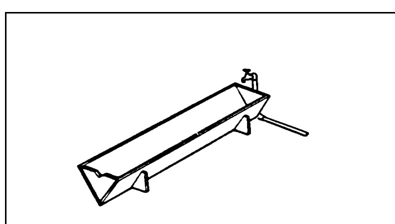


Fig 12-1-2 Trough for Washing Aggregate

staining, it must be washed. A trough suitable for washing aggregate is shown at Fig 12-1-2. Further tests for determining the cleanliness of aggregate are detailed at Annex A to this chapter.

12. **Water**. Water for concrete must be clean and free from oils, acids and organic material. Generally speaking, water that is fit to drink is suitable for concrete. Sea water may be used for mass concrete; however it will slow setting and hardening, but the ultimate strength will not be affected. Sea water shall not be used with reinforced concrete as it will eventually corrode the reinforcement.

SECTION 2

BATCHING AND MIXING

GENERAL

1. The measuring of materials for a concrete mix is known as batching. Concrete may be batched by volume, by weight, or by a combination of the two. Volume batching is normally used in the field where some loss in quality (due to aggregate) is acceptable.

WATER-CEMENT RATIO

2. The water-cement ratio is the amount of water to the amount of cement. It is normally expressed as the weight of water divided by the weight of cement, for example, if a batch contains 150 kg of water and 300 kg of cement, the water-cement ratio is 0.5. It may on occasions be expressed in terms of litres of water per bag of cement. Conversions from one term to the other, is a simple matter, since one litre of water weighs 1 kg, and normally a bag of cement weighs 40 kg.

3. The strength of concrete depends to a large degree on the water-cement ratio. This is because water which does not react with the cement eventually evaporates and leaves a network of voids throughout the concrete. The relationship between the water-cement ratio and strength is shown here.

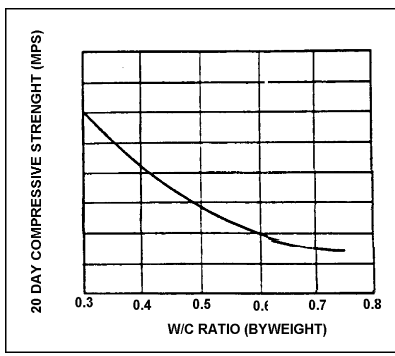


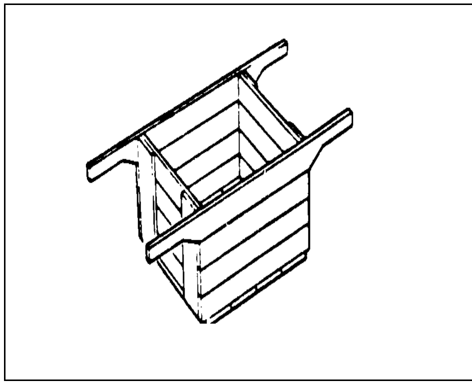
Fig 12-2-1 Effect of Water-Cement Ratio on Strength

4. It is not always possible to choose the ratio that will give the maximum strength, as other characteristics such as workability and finish, which may require a higher water content, must be considered. For the field engineer, determination of the correct water-cement ratio is largely a matter of experience.

VOLUME BATCHING

5. The quantities of materials in a batch are expressed in the form 1:2:4, 1:3:6 and the like. These figures indicate the proportions by volume of cement, dry sand and coarse aggregate respectively. Proportions and quantities of material for producing concrete in the field are shown in Fig 12-2-3. This table has different volumes for sand depending on whether it is moist or dry, because sand increases in volume when it is wet.

6. Volume batching can be conducted in the field using a gauge box, that is, an open box of known capacity fitted with handles (Fig 12-2-2). Quantities of materials are measured using the box and then emptied into the mix. To ensure that the box contains the correct amount, it should be filled to overflowing and the contents levelled off. The size of the box is not important but its capacity will provide a convenient unit of volume. It is also capable of being easily handled by two persons.



12-2-2 Gauge Box

7. Since cement is difficult to measure, it may be preferable to use a standard 40 kg bag and measure other materials in proportion.

WEIGHT BATCHING

8. On tasks where structural concrete is being prepared, weight batching must be used. Weight batching devices are fitted to most large concrete mixers. All materials are measured by weight although it may be more convenient to batch water by volume. This is acceptable because 1 litre of water weighs 1 kg. When weight batching sand, allowance is made for its moisture content. Compensate for wet sand by increasing the weight of sand batched and reducing the weight of water added. In the field, sand may be considered to be dry if it will pour fairly freely from the end of a shovel.

Class of work	Nominal mix (by volume, dry materials)	Approx quantities of materials per 40 kg bag of cement					Approximate Quantities of Materials per m^3 of mixed concrete					
		Sand		Coarse aggregate	Water		Cement	Sand		Coarse aggregate	Water	
		Dry	Moist		Dry aggregate	Moist aggregate		Dry	Moist		Dry aggregate	Moist aggregate
		m^3	m^3	m^3	l	l	kg	m^3	m^3	m^3	l	l
Structural reinforced conctrete road slabs, precast work	1:2:4	0.056	0.067	0.111	22	16	310	0.44	0.52	0.87	168	125
Ground floors, pavings, walls	1:2 ½:5	0.067	0.80	0.134	26	19	250	0.45	0.54	0.89	163	119
Foundations and mass concrete generally	1:3:6	0.084	0.010	0.167	31	23	220	0.45	0.55	0.91	166	122

ALL-IN AGGREGATE

Class of work	Nominal mix (by volume, dry materials)	Approx quantities of materials per 40 kg bag of cement		Approx quantities of materials per m^3 of mixed concrete		
		Dry Aggregate	Water	Cement	Aggregate	Water
		m^3	l	kg	m^3	l
Road slabs, paths	1:5	0.14	15	310	1:1	178
Unreinforced walls and partitions	1:6	0.18	18	250	1:1	178
Foundations and mass concrete generally	1:8	0.21	20	250	1:15	115

Fig 12-2-3 Proportions and Quantities of Concrete Materials

MIXING

9. **By Hand.** When mixing by hand, it is normal to batch by volume. For good results, proceed as follows:

a. mix on a clean, smooth and impermeable surface;

b. measure the coarse aggregate and place on the mixing surface first, followed by the sand, and then the cement;

c. mix thoroughly the dry contents before adding water; and

d. continually turn the mix as water is gradually added (preferably from a can fitted with a hose). Never use a hose, as a jet of water will tend to wash the cement from the mix.

10. **By Machine**. The mixer most likely to be used in field engineering tasks is the 11 cu ft ($0.31m^3$) trailer mounted mixer. For the best results with this or any other mixer:

a. make sure the mixer is level;

b. pour a small proportion of the water from the mix into the drum before commencing work. This will prevent cement paste accumulating around the blade roots;

c. do not waste time - approximately 30 revolutions of the drum is sufficient to ensure complete mixing; and

d. clean the drum immediately after use by running an aggregate and water mix in it for about two minutes.

PRE-MIXED CONCRETE

11. On site tasks where large quantities of concrete are required, pre-mixed or ready-mix concrete may be used. Pre-mixed concrete is prepared in a plant and transported to the site in a truck agitator or truck mixer. The capacity of pre-mix trucks ranges between 1 and 10 cubic metres. Because pre-mixed concrete is not prepared on site under supervision, it is important that it be tested before being accepted. The

slump test, as explained in Annex A, can be done easily on site and is a good measure of the quality of the concrete.

SECTION 3

PLACING, COMPACTING AND CURING

GENERAL

1. Whatever means of transporting and placing concrete are used, there are three things to bear in mind:

   a. **Time Factor**. Concrete must be placed and compacted before it sets. Therefore it is best to mix the concrete as near as possible to the task site. Concrete that has started to set must not be used unless plasticity can be restored by re-mixing without adding water;

   b. **Watertight Containers**. If containers are not watertight, water and cement will be lost and the concrete weakened; and

   c. **Segregation**. Segregation is the partial separation or unmixing of the concrete. It occurs chiefly in badly graded or over-wet mixes and may be caused by poor handling during transport, faulty placing or over compaction. In its commonest form, the coarse aggregate goes to the bottom and the cement and sand paste rises to the top. If it occurs during transport, the concrete must be re-mixed before being placed. It can be avoided during placing and compaction if proper methods are used.

TRANSPORTING

2. Unless concrete is transported in special agitator vehicles, vibration will cause segregation. Whenever possible, therefore, mixing will take place on site. When small quantities of concrete have to be moved in wheelbarrows, plank runways are put down and a proper traffic circuit worked out so as to avoid delays and keep vibration to a minimum.

PLACING

3. Good concrete will be ruined if it is carelessly and incorrectly placed.

a. Concrete shall be deposited as near as possible to its final position; lateral movement by shovelling shall be reduced to a minimum and if a chute is being used, the angle of the chute and the drop height will not normally exceed 45 degrees and 1.5 m respectively.

b. Concrete is placed in even layers and compacted before the next layer is deposited. The thickness of layers will depend on the methods being used for depositing and compaction, the width of the section, and whether reinforcement is being used. Generally speaking, 150 - 300 mm for reinforced work, and up to 450 mm for mass concrete can be taken as a guide.

c. Concrete shall always be placed towards the face of the concrete already in position (Fig 12-3-1). This assists compaction and lessens the risk of segregation

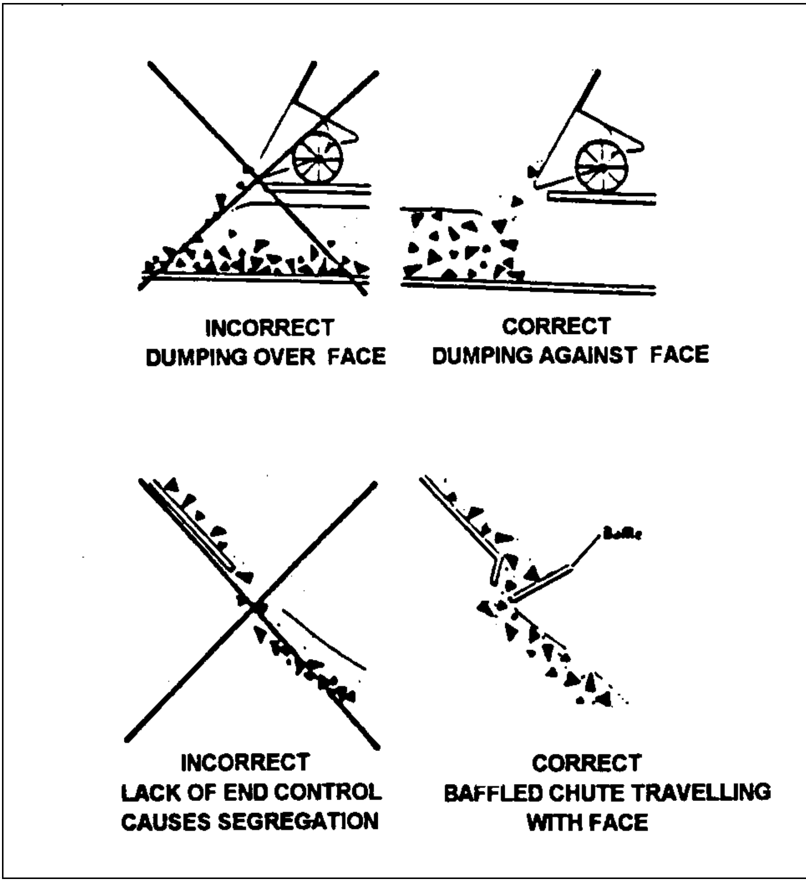


Fig 12-3-1 Placing Concrete

d. The amount of concrete placed before it is allowed to harden is known as a lift. Continuous pouring in a single lift produces a joint-free structure. In high structures, for example walls, the lift is usually limited to about 1.5 m in order to avoid the necessity of very heavy and elaborate formwork. With large slabs, the lift is limited by the need to control shrinkage cracks.

e. The surface of a completed lift shall be kept straight and level, ready for jointing to the next lift.

f. If concrete is placed in excavations, for example foundations, any accumulated water shall be removed before the concrete is deposited. If the surrounding soil is dry and absorbent, it will be thoroughly soaked with water immediately before the concrete is placed or alternatively covered with a layer of polythene or similar material.

g. Formwork shall be cleaned before concrete is placed and the surfaces painted with form oil or sump oil to prevent the concrete from sticking. This will be done before any reinforcement is fixed in position.

COMPACTING

4. **Hand Compaction**. Hand compaction can be done by rodding, tamping or ramming:

a. **Rodding**. Rodding is used for compacting thin vertical sections, such as walls. It is done by inserting a rod, for example, a length of reinforcing bar, vertically into the concrete and working it up and down until the concrete is thoroughly worked into place. Special attention is required at corners and other awkward spots;

b. **Tamping**. Tamping is used for slabs, for example, roads and floors. If a tamping rule is used, this also serves to finish the concrete to the required level. Tamping in practice usually only involves the screed board "jumping" over the concrete surface; and

c. **Ramming**. Ramming is reserved for heavy masses of unreinforced concrete, for example, bridge pier foundations. The rammer face shall be at least 150 mm square. When ramming use a similar action as that used when rodding; however, more force will need to be applied because of the tool shape.

5. **Mechanical Compaction**. Mechanical compaction may be done with an immersion vibrator or a surface vibrator (Fig 12-3-2). Mechanical vibrators allow a drier mix to be used. This results in higher strength and reduces shrinkage and voids. Whatever method of vibration is used, compaction stops when free water and cement paste come to the surface.When using an immersion vibrator insertion from 5 to 15 seconds at 40 cm spacings is recommended. If compacting in layers, it shall penetrate slightly into the previous layer

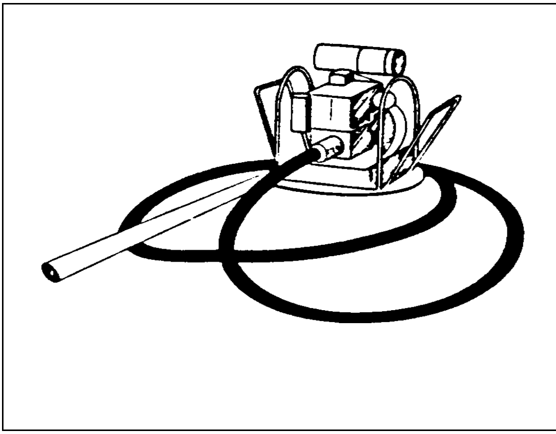


Fig 12-2-3 Typical Poker Vibrator

6. **Immersion Vibrators**. Immersion vibrators may be mechanically, electrically or pneumatically driven. They are sometimes referred to as internal or poker vibrators and are the most effective type available as they vibrate the concrete directly. They are available with heads ranging from 25 to 150 mm diameter. The 60 to 70 mm head is the most common general purpose type.

7. **Form Vibrators**. Form vibrators, sometimes referred to as external vibrators, are attached to the outside of forms by means of clamps, and impart oscillations or shaking motions of the forms. This type of vibrator is suitable for small members or narrow and heavily reinforced sections into which it is difficult to insert immersion vibrators. They are often used in conjunction with poker vibrators (Fig 12-3-2) when a high degree of compaction and good dense surface finish is required.

8. **Surface Vibrators**. Surface vibrators are used for floors, road slabs and other thin sections with large surface areas. Surface vibrators normally consist either of a flat pan or tray with handles at either end and a vibrating unit mounted in the middle, or a screed board with one or more

vibrating units fixed to it. Surface vibrators are not generally effective beyond depths of 175 mm.

FINISHING

9. Finishing is the process of levelling and smoothing concrete to obtain the required finish.

10. **Placing and Screeding**. Immediately after placing and compacting, a screed board (straight-edge) is used to quickly level the concrete. The screed board is moved forward with a sawing motion so that a small amount of concrete is always pushed ahead of the screed. Concrete is shovelled towards or away from the front of the screed as necessary.

11. **Edging and Jointing**. After the initial screed, edging and control joints should be made. Immediately verify the level with a straight-edge or template. Make every effort to ensure the initial finish produces surface levels within specified tolerances but avoid overworking the surface. Final finishing only removes minor imperfections. It does not correct levels.

12. **Finishing**. Working the surface too soon will create a weak surface and produce laitance (the milky looking scum or cement paste). Working the surface too late will require considerably more finishing effort and may cause crumbling. While the correct delay is most important to the production of a quality finish, the length of delay required will vary as it depends on many factors, including concrete temperature, type of concrete, quantities of water and cement used, weather conditions, depth of pour, type of aggregate and type of subgrade. Never attempt final finishing in any area where there is free surface water and never use powder cement to dry up surface moisture as this causes surface cracking.

13. **Floating.** After the sheen has left the surface, floating commences, normally with a wood float. Floating is the operation of smoothing out irregularities in the surface following screeding, and:

   a. embedding large aggregate below the surface;

   b. removing imperfections;

   c. providing a denser and in some cases smoother surface;

d. preparing the surface for other finishing operations, for example, trowelling or brooming; and

e. closing minor cracks which can occur as the surface dries.

14. **Trowelling and Power Floats**. Steel floats are used to provide a smooth, dense and hard surface. This is called trowelling. Trowelling produces a surface which is durable and easy to clean, but slippery when wet. Power floats will reduce labour requirements when trowelling. Power floating is done with a rotating steel disc or a power trowel fitted with steel floats. Hand trowelling cannot commence until mechanical floating is completed.

15. **Brooming**. Brooming is a method of obtaining a non-skid surface. After floating is complete, a medium soft bristle broom is drawn lightly across the surface to roughen it.

CURING

16. The amount of water in a correctly proportioned mix is sufficient to enable the concrete to reach the required strength provided water is not lost during setting and hardening. Water can be lost as a result of heat generated, evaporation or absorbtion by surrounding materials. The prevention of loss from heat and evaporation is known as curing, and is of vital importance during the early days of hardening. Curing must start as soon as possible after the concrete is placed and must continue, in the case of type 10 cement, for seven to ten days, and for rapid hardening cement (Type 30) for four to seven days. These are minimum figures as the strength of concrete increases as long as moisture is present. Curing also reduces cracking due to shrinkage.

17. The method of curing used will depend on the type of structure and the materials available. If the concrete is completely enclosed in forms, the forms shall be left in place and kept wet. If the forms have to be removed for use elsewhere, the concrete shall be constantly sprayed or draped in plastic. If a slab is to be cured, it shall be completely covered with plastic or with hessian that is kept wet. If these materials are not available use clean wet sand.

SECTION 4

JOINTS

GENERAL

1. The two types of joints that the field engineer is concerned with are construction joints and expansion joints. Construction joints are formed where new concrete is bonded to existing concrete. Expansion joints are included in large work such as vehicle parks to allow for the expansion and contraction of the concrete.

CONSTRUCTION JOINTS

2. A construction joint is a concrete joint made in such a manner that the faces of new and old concrete bonds sufficiently to prevent any movement across the joint. Unless they are properly made, the joint will be a weakness in the structure.

3. **Location of Joints**. In important work, the location of construction joints will be specified and may not be made anywhere unless approved by a qualified engineer. In other work where detailed specifications are not given, the following may be used as a guide:

   a. **Columns and Walls**. Columns and walls that are to support a beam are finished-off level and about 155 mm below the underside of the beam. This will enable the beam and the remainder of the column or wall to be poured together.

   b. **Supported Slabs and Beams**. Joints in supported slabs and beams are to be made at the mid-span if possible. They shall never be made outside the middle third of the span.

   c. **Structures with Expansion Joints**. Construction joints are never to be made between expansion joints.

4. **Making Construction Joints**. When a vertical construction joint has to be made in a beam or slab, a stop or bulkhead is used to ensure a vertical joint is formed. If the concrete is left free, it will adopt its natural

angle of repose and will be impossible to compact thoroughly. This will result in a weak, porous joint. Reinforcement is not to be cut at a construction joint; therefore stop boards (Fig 12-4-1) are to be either built in segments or slotted to cater for the reinforcement. When making a horizontal joint, it is important to remove the weak layer of porous concrete which forms during placing and compaction. For all construction joints, the old surface shall be prepared to receive the new concrete. To prepare the old surface:

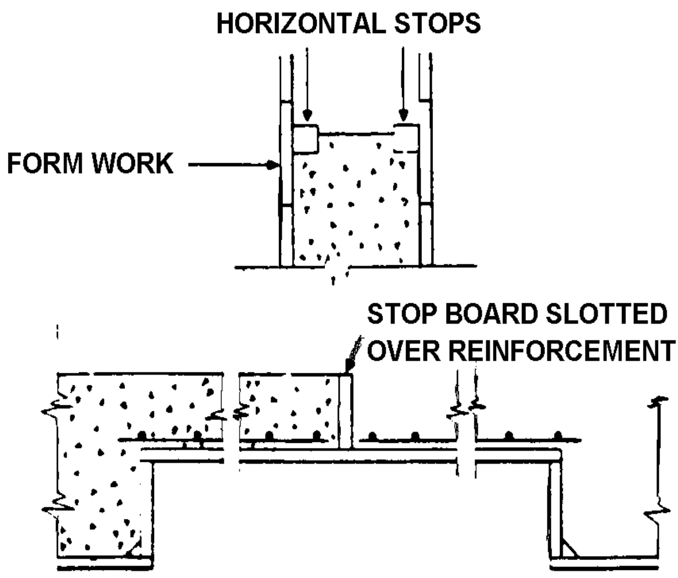


Fig 12-4-1 Use of Stop Boards

a. remove the stop boards, if used;

b. expose the aggregate in the concrete already placed by cleaning off any laitance (cement residue) by scrubbing and wire brushing. If the concrete has hardened, a cold chisel may be needed. Be careful not to dislodge pieces of coarse aggregate;

c. remove all loose material and dust, and thoroughly wet the surface;

d. remove any free water;

e. brush a thin layer of cement grout (cement and water) well into the surface. If the old concrete has hardened, follow the grouting coat with a layer up to 25 mm thick of mortar (one part cement to two parts sand); and

f. place the fresh concrete, ramming it well against the old, paying particular attention to edges and corners.

EXPANSION JOINTS

5. Expansion joints are incorporated into structures to allow for expansion and contraction. They are usually designed by a qualified engineer and their location specified in the drawings. However, on routine or less important work, for example, pathways or small slabs, field engineers will be required to locate and construct expansion joints. These joints will be restricted to contraction (control) joints.

6. **Control Joints**. Control joints are concrete joints made by creating a plane of weakness in a slab or wall along which the concrete will crack when it shrinks. They are made to relieve the stresses caused by shrinkage and if they are not incorporated, random cracking will occur. Control joints are not generally made in concrete which contains reinforcing steel because shrinkage is restricted by the steel. Two methods of creating a control joint are shown in Fig 12-4-2. A wooden fillet is used when the cement is over 150 mm deep. For cement less than 150 mm deep, a grooving tool will create a plane of sufficient weakness.

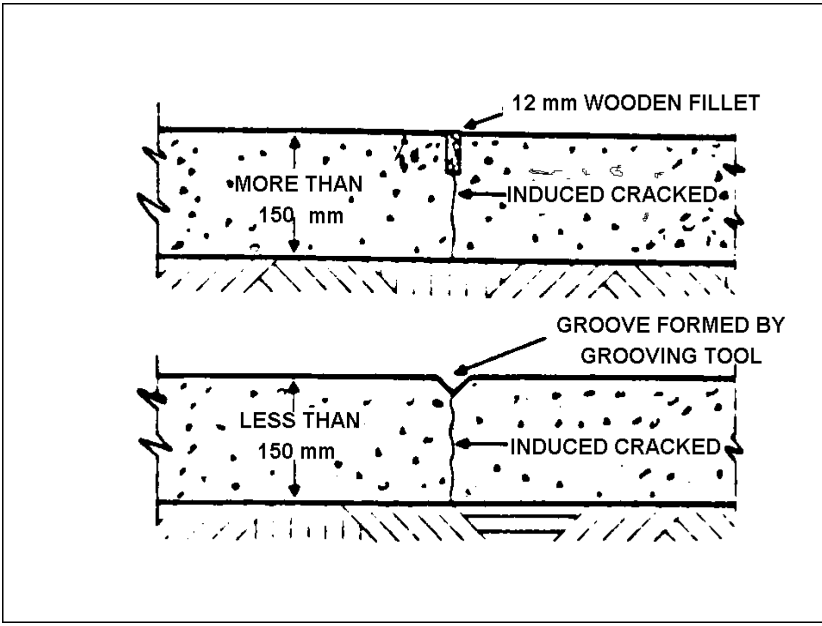


Fig 12-4-2 Control Joints

7. Control joints will be located where the concentration of stresses is expected to occur, for example, at abrupt changes in cross-section, and where structures are weakened by openings.

8. In long or large unreinforced slabs, such as roads or hardstands, control joints will be required periodically to prevent random cracking. As a guide, slabs are divided into square bays by means of control joints. These bays also provide convenient points at which to interrupt the placing of concrete. In all cases, alternate bays shall be poured first and gaps filled in later. In this way, partial shrinkage of half bays occurs prior to placing the remainder.

SECTION 5

SIMPLE REINFORCED SLABS

SIMPLE REINFORCED SLABS

1. Concrete is relatively strong in compression but weak in tension. In a loaded horizontal slab or beam, supported at both ends, the upper part of the beam is in compression, and the lower part is in tension. To obtain the maximum load capacity, steel reinforcement is inserted in the tension side to bring its strength up to that of the compression side (Fig 12-5-1).

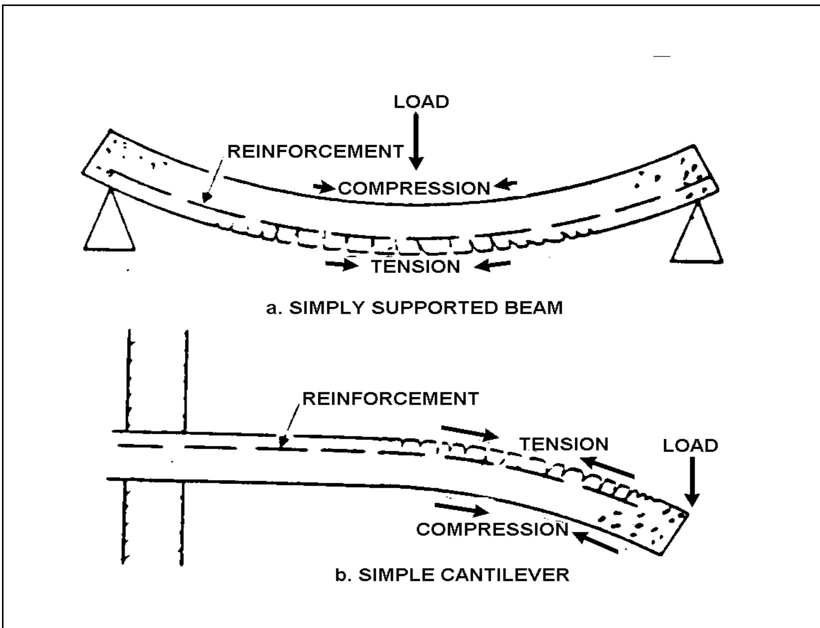
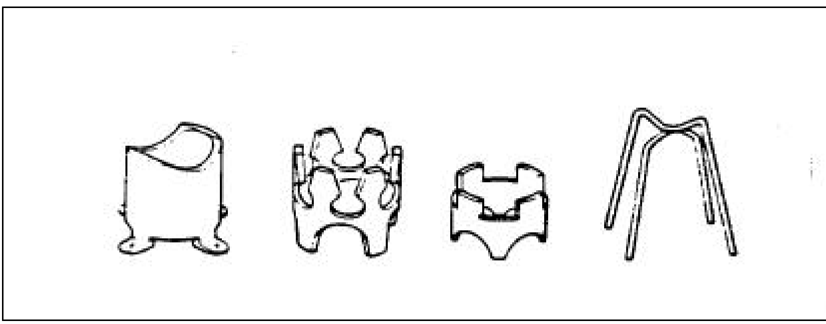


Fig 12-5-1 Reinforcement Position

2. The most common forms of reinforcement are plain bars, deformed (twisted) bars, and wire mesh. Concrete reinforced with bars shall be designed by a qualified engineer and is outside the scope of this manual. Wire mesh is simple to use, and it is almost standard practice to employ it in slabs.

3. Wire mesh will usually be available in the field in the form of square or rectangular mesh. It is formed from bars or wires welded at all points of intersection and is supplied in sheets or rolls. Before the mesh is used, it is cleaned of loose rust, mill scale and foreign matter such as dirt, oil or paint.

4. All reinforcement shall be covered by a minimum depth of concrete, usually 30 mm. To ensure that the correct cover is maintained, it is important to prevent the reinforcing from moving when the concrete is poured. This is achieved by using spacers. They may be manufactured or locally produced concrete blocks. If concrete blocks are used, the mesh is tied to them with wire to prevent movement (Fig 12-5-2). When mesh sheets are used, they must be joined end to end by a 30 mm overlay. Side overlay is not necessary.



Fir 12-5-2 Spacers

SECTION 6

FORMWORK

CONSTRUCTION

1. The term formwork describes the temporary structure erected to hold wet concrete in place until it is sufficiently hard and strong to be self-supporting.

2. On large tasks, formwork is designed by the engineer, while on routine jobs, this is the responsibility of unit tradesmen. Manufactured steel forms are now used for many important tasks, but in the field, these are not normally available and materials such as timber, steel and corrugated iron have to be used. Typical timber forms for a wall and column are shown below.

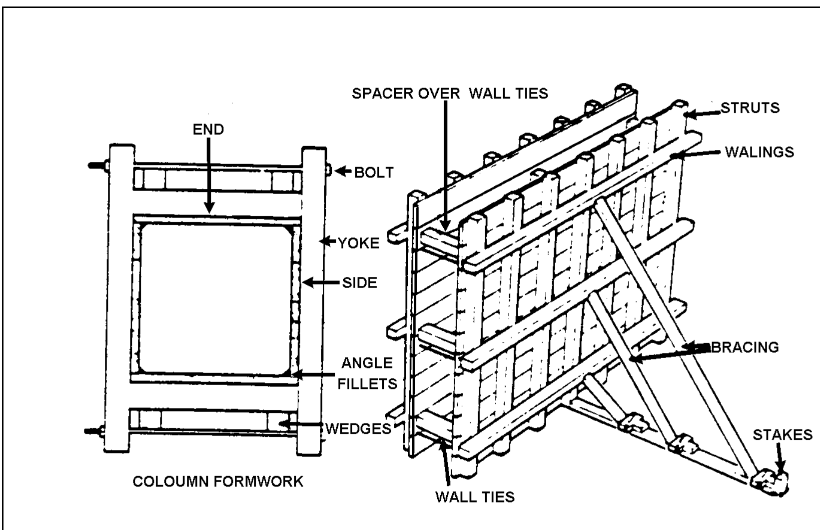


Fig 12-6-1 Typical Formwork

3. Whenever formwork is constructed, two points must be kept in mind:

a. the formwork shall be strong enough not to deflect under load; and

b. the formwork shall be constructed so that it can be dismantled without damaging the concrete.

4. To permit safe and easy dismantling, the following construction points shall be observed:

a. hold panels in place by struts, braces and wedges;

b. leave nail heads protruding so that they can be easily withdrawn; and

c. oil the inside of the sheeting to prevent it sticking to the concrete. Care is required however, to ensure that oil does not come into contact with the reinforcing steel as it will prevent bonding.

REMOVAL AND MAINTENANCE

5. Formwork is stripped and removed with care so as not to damage the concrete. Bracing should be eased off gradually to avoid imposing sudden loads on the structure, and if levelling is necessary, this should be done against the formwork not the concrete.

6. Minimum removal times depend on the type of structure and cement used, the properties of the mix and the weather. The times given in Fig 12-6-2 shall be treated as a minimum. Remember that the formwork helps retain the moisture in concrete and is thus an aid to curing. Always leave it in situ for as long as possible, up to a maximum of 28 days.

Member Type	Member	Effective Span (m) (note)	Minimum Stripping Time (days) for Average Air Temperature During Period Prior to Stripping			
			20°C and over	10°C to 20°C	5° C	Under 5° C
Vertical, unloaded	Wall, column, beam side	-	2	3		7
Vertical, load bearing	Wall, column or load bearing structure	-	5	6	7	9
Horizon-tal load bearing	Slab	Under 3	7	10	14	21
		3-6	10	14	21	28
		Over 6	14	21	28	28
Horizon-tal load bearing	Beam	Under 3	10	14	21	28
		3-6	14	21	28	28
		Over 6	21	28	28	28

NOTE: Effective span is the maximum distance between supports (either temporary or permanent).

Fig 12-6-2 Recommended Minimum Stripping Times in the Absence of Calculation and Strength Testing

SUPERVISION

7. There are many things that can go wrong in the production of concrete. Close supervision at every stage is essential, and, in particular, shall ensure that:

a. the quality of materials is maintained; check particularly the storage arrangements for cement, the grading and cleanliness of aggregates and the quality of water;

b. batching quantities are consistent and allowance has been made for any moisture in the aggregates;

c. the distance over which concrete is transported is kept to a minimum;

d. the correct placing techniques are used;

e. reinforcement and formwork is correctly positioned and secure before placing concrete;

f. layers are compacted in the correct thickness and that over compaction does not occur; and

g. correct curing procedures are used for the required length of time.

ANNEX A

TESTING AGGREGATE AND CONCRETE

TESTING AGGREGATE

1. As aggregate may contain excessive amounts of dirt, salt or organic impurities which can seriously weaken concrete, tests shall be regularly made even on the most simple jobs.

2. **Clay and Fine Silt Test** (Fig 12A-1). To test for the presence of clay and fine aggregate:

a. prepare a salt solution by adding one teaspoon (5 ml) of salt to 500 ml of water;

b. place about 50 ml of the salt solution in a 250 ml bottle;

c. pour aggregate into the bottle until the measured volume is 100 ml;

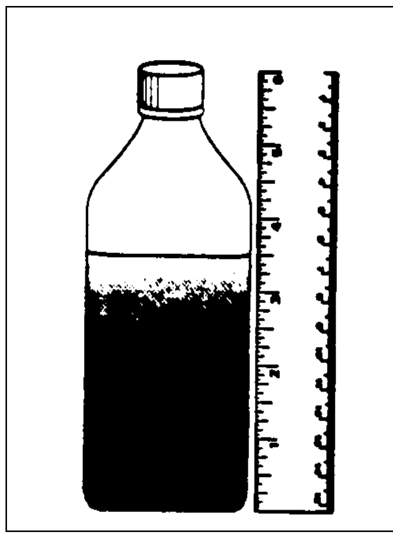


Fig 12A-1 Silt Test

d. make the volume up to 150 ml by the addition of more salt solution;

e. shake the mixture vigorously and allow to stand for three hours; and

f. check the volume of the aggregate and the volume of settled silt. If the depth of the clay and silt layer is more than 10 percent of the total depth of the aggregate, reject the aggregate.

3. **Organic Impurities Test** (Fig 12A-2). To test for the presence of organic impurities in fine aggregate:

a. prepare a three percent solution of caustic soda (30 grams of sodium hydroxide in 970 ml of water);

b. pour 50 ml of the solution into a calibrated bottle;

c. add aggregate to the 125 ml mark and then top up with caustic soda to the 200 ml mark;

d. shake the mixture and allow to stand for approximately 24 hours; and

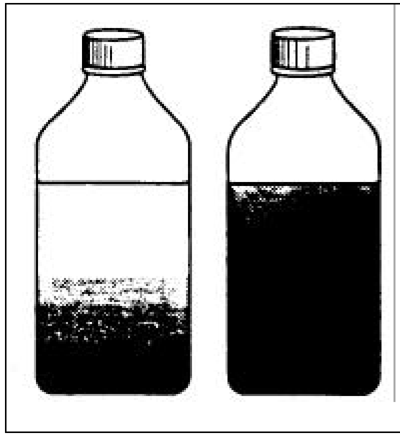


Fig 12A-2 Organic Impurities Test

e. examine the colour of the solution. If it is darker than the colour of light straw, organic material may be present, and further tests, carried out by a person qualified in soil analysis, are required.

TESTING CONCRETE

4. **Slump Test** (Fig 12A-3). The slump test is a measure of the consistency (workability) of concrete and is also a simple means of ensuring that each batch delivered is uniform. Sufficient tests should be carried out each day to check that uniformity is being maintained. The allowable limits will be specified by the project engineer who ordered the work. Variations in water content of the concrete usually result in variable strengths. Other factors which can affect the slump are the grading and particle shape of the aggregate and the cement content.

5. A consistent slump usually means that the concrete is under control. If the results vary, it means that something has varied, usually water. Equipment for the slump test consists of a standard slump cone, a

bullet pointed steel rod, a rule, a bucket in which to sample the concrete, and a scoop. The test should be made on a level, non-absorbent surface.

6. To determine the slump of a concrete sample:

a. place the test cone on a level surface (large end down) and hold firmly in place using foot rests;

b. place concrete in the cone to a level of one fifth the height of the cone;

c. rod the concrete 25 times with the steel rod distributing the strokes evenly over the concrete;

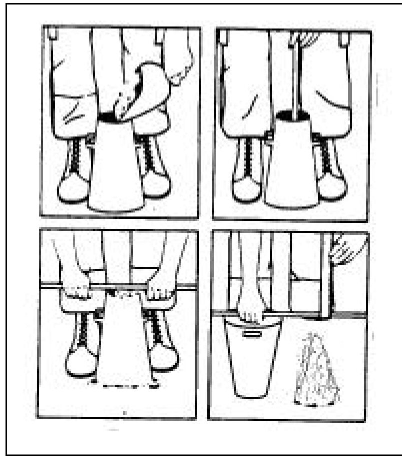


Fig 12A-3 Slump Test

d. add a second layer of concrete to half the height of the cone;

e. rod the second layer 25 times, allowing the rod to just penetrate to the layer below;

f. add a third layer of concrete to the top of the cone;

g. rod the third layer 25 times allowing the rod to just penetrate to the layer below;

h. strike off any excess concrete so that the concrete is level with the top of the cone;

j. immediately lift the cone carefully but firmly from the concrete; and

k. measure the distance the concrete has subsided to the nearest 5 mm. This distance is known as the slump. If the concrete collapses laterally or shears (Fig 12A-4) adjust the mix.

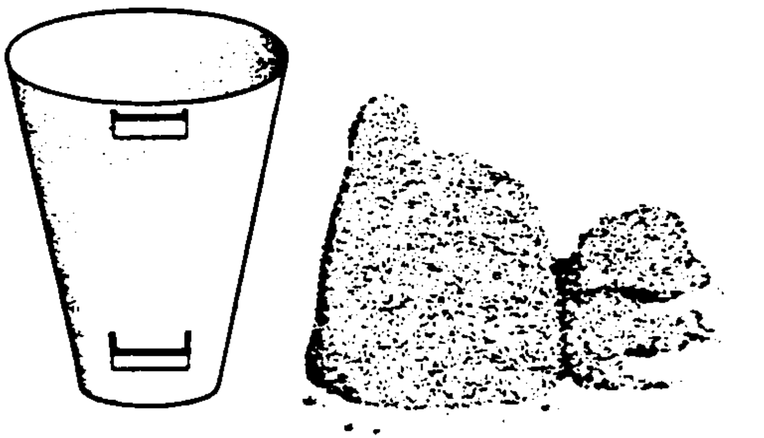


Fig 12A-4 Slump Test Failiure

CHAPTER 13

TIMBER JOINTS AND SPLICES

GENERAL

1. The most common form of structure that is likely to be encountered in field engineering is one which supports a weight above floor level, for example, a shelter with overhead cover, a trestle to support the deck of a bridge or a framework to support camouflage nets. The principle on which such structures are usually designed is that horizontal members are placed immediately under the load, and vertical members are used to transfer the weight from the horizontal members to the ground. The type and location of joints in horizontal members depends on the type of structure and the weight carried.

TIMBER JOINTS

2. Plain butt joints will always be used in field engineering. Housed joints are made by tradespersons since they take time to make, and unless cut accurately, seriously weaken the timber. A plain butt joint requires a flat bearing surface on each member and therefore, if round timber is being used, a notch must be cut to supply it. These notches shall never be deeper than one-sixth of the diameter of the timber.

3. Two or more members of a timber framework can be joined together by using:

   a. iron nails, spikes, bolts or dogs which clamp the two members together; or

   b. timber stops, distance pieces and coverplates (the notches referred to earlier fulfil the role of stops).

4. Fig 13-1 shows suitable joints for a framework of round timber and Fig 13-2 for a framework of squared timber.

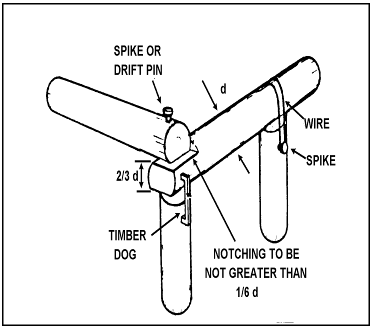


Fig 13-1 Suitable Joints for Framework of Round Timber

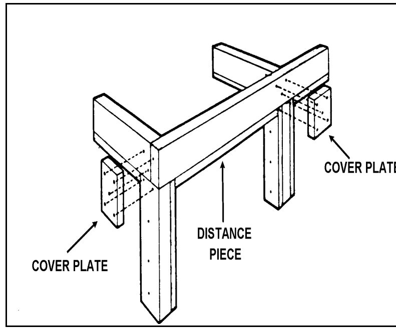


Fig 13-2 Suitable Joints in a Framework of Squared Timber

5. **Baseplate**. A baseplate is one method of distributing the load over a safe area of ground so that the upright does not sink in. Fig 13-3 shows an improvised baseplate at the foot of a post which is held in position by stops nailed to the plate.

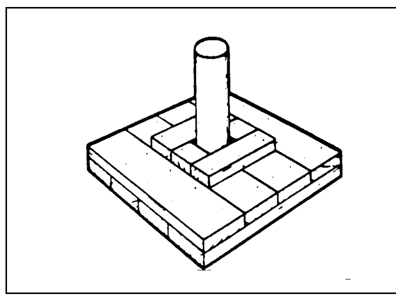


Fig 13-3 Improvised Base Plate

6. Additional timber joints that are commonly used by the field engineer are described in the following paragraphs:

a. **Straight Butt Joint**, formed by bringing the square cut end of one board against the square face of another. Nails or screws are used to hold the pieces together.

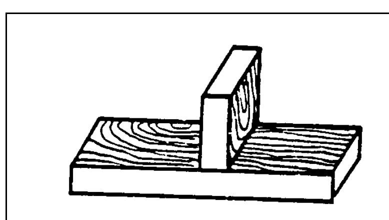


Fig 13-4 Straight Butt Joint

b. **Oblique Butt Joint**, formed by bringing the end of one board, cut on the oblique to form the desired angle against the face of another board. It is commonly used for bracing, and should not be used where great strength is required.

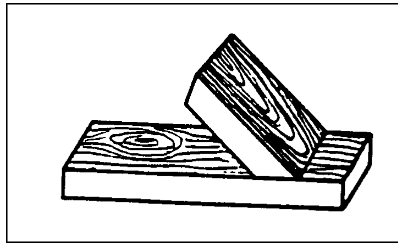


Fig 13-5 Oblique Butt Joint

c. **Mitre Joint**, used extensively in framing but provides a very weak joint. To form a right-angle mitre joint (the most commonly used) each piece is cut at a 45 degree angle to form a 90 degree angle when joined.

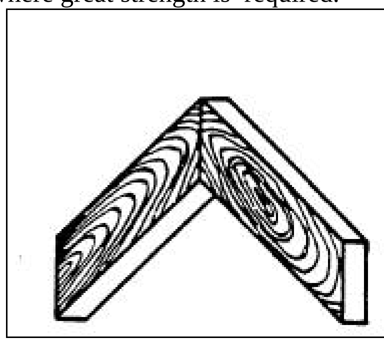


Fig 13-6 Mitre Joint

d. **Plain Lap Joint,** formed by laying one board over another and securing them by screws or nails. It is most often used in framing and construction and is as strong as the fasteners and material used.

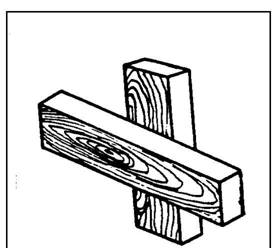


Fig 13-7 Plain Lap Joint

TIMBER SPLICES

7. The following timber splices may be used in field engineering:

a. **Half-Lap Splice Joint**, formed by cutting away portions (usually half) in equal lengths from the thickness of two boards and joining them in such a manner that the cut-away portions overlap in a complementary manner to form the joint. It is an easily made joint and relatively strong.

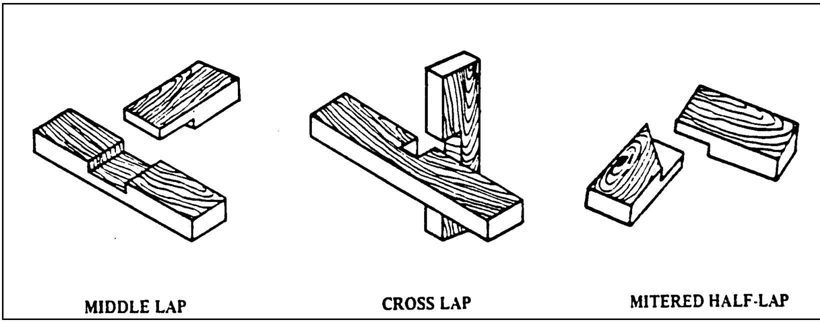


Fig 13-8 Variations of the Half Lap Joint

b. **Butt Splice**, formed by butting the squared ends of two pieces of lumber together and securing them in this position with wood or metal pieces.

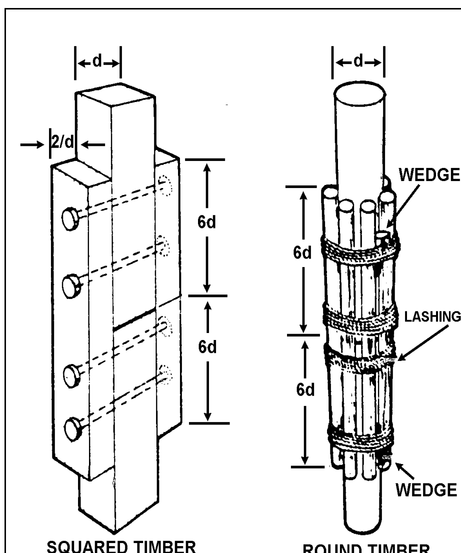


Fig 13-10 Butt Splices in Square and Round Timber

c. **Bend Resistant Splice**, formed by cutting oblique complementary laps in the ends of two pieces of timber. The upper tongue is squared to butt against The square of the complementary lap and the lower tongue is bevelled. A scab or fishplate may be fastened along the bottom

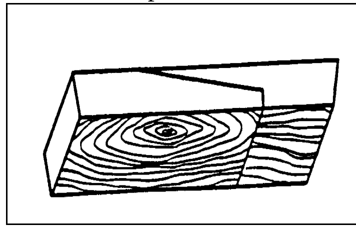


Fig 13-9 Bend Resistant Splice

d. **Halved Splice**, formed by cutting away half the thickness of equal lengths from the ends of two pieces of timber and fitting the complementary tong ues to-gether. Nails or bolts are used to fasten them. Fishplates or scabs may also be used

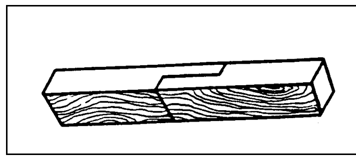


Fig 13-11 Halved Splice

e. **Long Plain Splice**, a hasty splice with a long overlap of the two pieces to provide adequate bearing surface and enough room for fasteners.

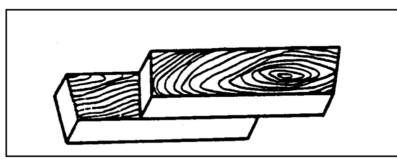


Fig 13-12 Long Plain Splice

CHAPTER 14

BASIC BRIDGING

SECTION 1

GENERAL

TYPES

1. Bridging in its broadest interpretation covers every means of crossing a gap, including fords, earth ramps, amphibious vehicles, boats (such as landing craft and assault boats), rafts and bridges. It can range in scope from a simple diversion for tanks in a forward area to permanent road or railway bridges over a major river. Bridges are classified as either equipment or non-standard (NSB). They may be fixed or floating, and can be constructed of steel, light alloy, timber, or material at hand.

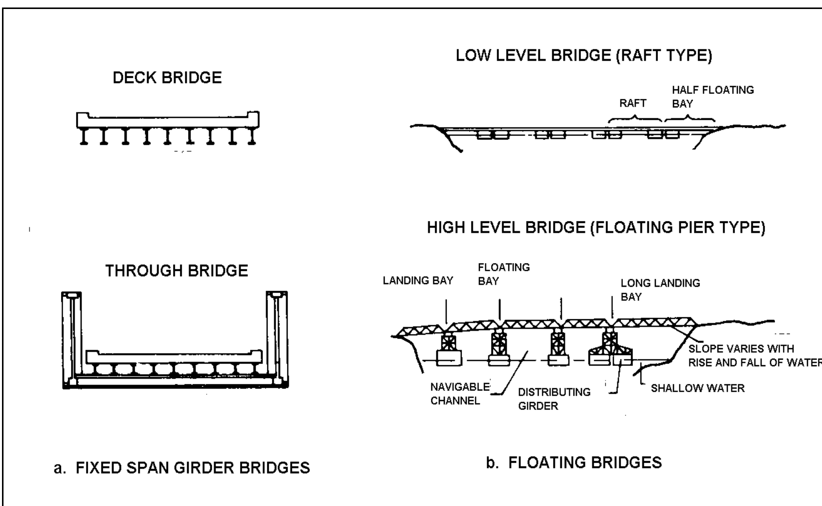


Fig 14-1-1 Types of Bridges

2. Fixed bridges may be of the girder, suspension or arch type. Most construction work is on girder bridges. Suspension bridges for light loads are built occasionally, and arch bridges are rarely built. The two main types

of girder bridges are the deck bridge and the through bridge. A through bridge carries the deck within the super-structure, while a deck bridge has the deck above it.

3. Floating bridges may be either low level or high level (Fig 14-1-1). The latter are used to give clearance beneath the spans for river traffic or where the banks are high and steep or where the river is subject to tidal or seasonal variations.

PARTS OF A BRIDGE

4. **Abutment**. An abutment normally performs three functions: it supports the end of the bridge, it acts as a retaining wall or revetment to prevent the bank or embankment from collapsing, and the wing walls prevent the end of the bridge from being undermined or eroded during floods.

5. **Bankseat**. The bankseat carries the load of the end of the bridge and it may form part of the abutment. It is comprised of two main parts, the bridge seat or bearing plate on which the main girders rest, and its foundation, usually a grillage.

6. **Pier**. A pier is an intermediate support between two bankseats. Piers may be fixed or floating. Various examples of fixed piers are shown in Section 2.

7. **Trestle**. A trestle is a particular form of pier, often adjustable in height and used in the construction of non-standard bridges. The double bent is two trestles joined together with “Z” bracing to form a pier.

8. **Span**. The span is the length between two piers, trestles, bankseats or bankseat and pier in any order or combination.

9. **Transom or Cross Girder**. A transom or cross girder is a cross member between the main girders of a through bridge or the legs of a trestle, that carries the roadbearers

10. **Roadbearers**. A roadbearer is one of the longitudinal members that carry the superstructure. The stringers in certain equipment bridges perform the same function.

11. **Superstructure**. The superstructure includes the decking, ribands (which hold the decking in place and also act as wheel guides), the wearing surface, footwalk and handrails.

12. **Grillage**. Grillage is a heavy framework of crossed timbers or metal beams which form the foundation for the bridge.

BANKSEATS FOR DECK BRIDGES

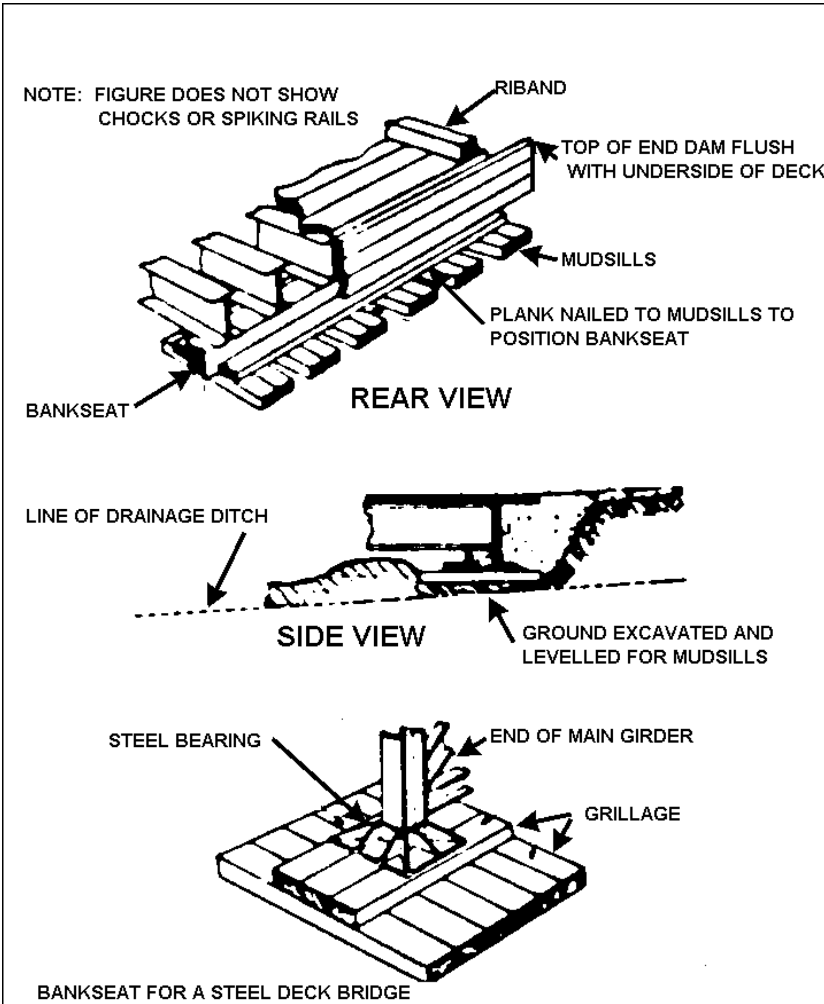


Fig 14-1-2 Bankseats

13. The following points shall be noted when preparing bankseats for deck bridges:

a. the bridge seat shall consist of a single length running the full width of the bridge;

b. the ground shall be excavated to the required level over the whole area of the mudsills, allowing 15 to 30 cm clear area to facilitate positioning. In estimating the depth, an allowance of 3 cm for settlement is generally made;

c. drainage ditches shall be dug as the excavation proceeds. Water must not be allowed to accumulate in the excavation;

d. if an existing concrete or rock abutment is being used, the mudsills will be unnecessary, but a 3 cm cushion of sand shall be laid instead to ensure an even bearing for the bridge seat; and

e. the end dam shall extend laterally beyond the outer girder or roadbearer at least 90 cm. The excavation immediately behind the end dam must be filled with rubble or crushed rock. If unavailable, well-tamped earth may be used.

14. **Design.** To design a simple bankseat for a deck bridge:

a. determine the maximium load which will be imposed on the bankseat;

b. determine the safe bearing pressure that can be placed on the soil. A normal guide is:

(1) good ground - 2000 kg per square foot;

(2) poor ground - 1000 kg per square foot; and

(3) mud - 250 kg per square foot; and

c. determine the bearing area of the mudsill which must be contact with the ground. The normal size timber bridge seats are:

(1) for loads up to 27.2 tonnes - 150 mm x 150 mm;

(2) for loads between 27.2 and 68 tonnes - 228 mm x 228 mm; and

(3) for loads over 68 tonnes - 304 mm x 304 mm.

BANKSEATS FOR THROUGH BRIDGES

15. There will normally be a separate bankseat under the end of each main girder and since the load is often considerable, a grillage of several layers is necessary. With bridges of Class 80 and over, at least part of the grillage will often be of steel beams and sub-paragraphs 13 b, c, and d apply.

16. **Design**. The procedure for deck bridges is followed. However, the maximium load under each girder is unlikely to exceed two-thirds of the total end reaction. The same size timber bankseats should be used.

GRILLAGES

17. For grillages on normal ground, the most essential matter is getting the bottom layer level in all directions. If the soil is stoney, either the large stones are removed or a cushion of sand is laid to provide an even bearing surface for the timber.

18. If separate rolled steel joists (RSJ) provide one layer of the grillage, the design will include fixing spacing blocks between the joists to avoid overturning. Methods of fixing spacing blocks are considered in Section 4.

19. For grillages on soft ground, a semi-flexible mat shall be provided since a stiff grillage will settle unevenly. A common design is matting with a layer of wire mesh track on top. Steel bridging cribs are then built up on the mat to the desired height. The size of the mat must extend a minimum of 1.3 m beyond the outer edge of the cribs.

SECTION 2

PIERS

CRIB PIERS

1. **Timber Crib Piers.** A typical timber crib pier design using railway sleepers is shown in Fig 14-2-1. Points to note in construction are:

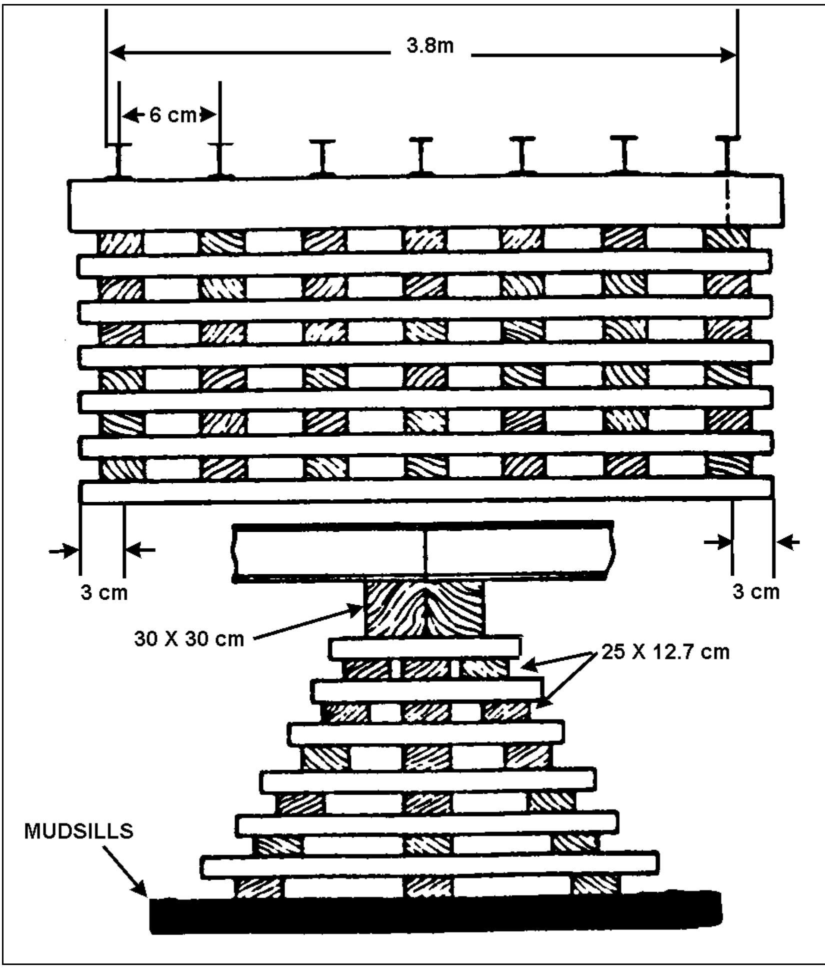


Fig 14-2-1 Timber Crib Pier

a. the foundation shall be level and each successive layer shall also be level;

b. each successive layer shall be securely fastened to the layer below. Bolts, nails, spikes, wire or cordage may be used. For work of a very temporary nature, fastening is sometimes dispensed with;

c. the width of the base shall never be less than one-third the height;

d. the longer sides shall be given an inward slope of 3:1 to provide stability against longitudinal forces, for example when launching the girders; and

e. the points of support, where successive layers cross, shall come immediately under the load and shall be carried through vertically, or nearly so, from the top to the bottom of the crib.

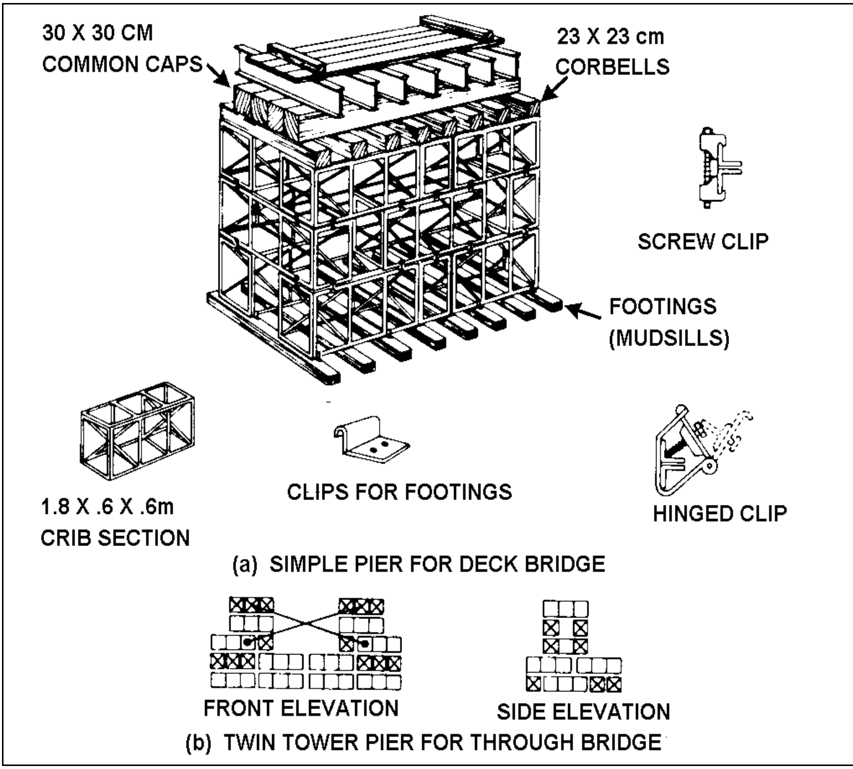


Fig 14-2-2 Piers of Steel Bridging Cribs

2. **Steel Cribs**. Fig 14-2-2 shows the standard equipment 18 tonnes (Christchurch) bridging crib and a simple pier built of such cribs. The permissible load is 4.5 tonnes on a panel point, therefore a total of 18 tonnes is permitted on the end of a crib standing upright or 36 tonnes on the side of a crib used horizontally. A 18 tonne steel bridge crib weighs approximately 90 kg (200 pounds). Points to note in construction are:

a. the crib is to be loaded, as far as possible, at panel points only. For that reason, levelled groundsills and capsills of heavy bulk 30 cm by 30 cm are provided;

b. the cribs in any layer shall be laid at right angles to those in the layers above and below, again with panel points coinciding; and

c. the pier finishes in two towers to take the baseplates of a through bridge and sway bracing is essential. The clips are not designed to maintain rigidity (Fig 14-2-2).

3. **Box Cribs**. The box (bottom and four sides) is made of layers of logs lashed or spiked together and is filled with coarse graded stone. The stone filling carries the load while the logs keep the stone in place. Box crib piers are useful in fast flowing streams where the bottom is too hard for piles to be driven and the depth of water is not too great to allow the use of engineer heavy equipment for loading stone.

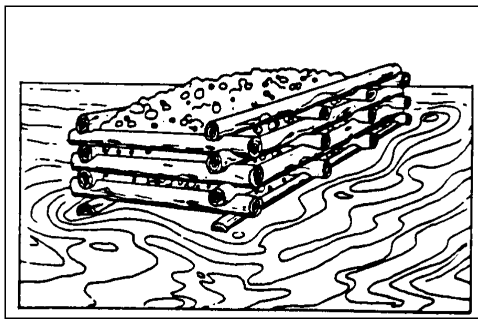


Fig 14-2-3 Box Crib Pier

4. The method of construction shall be adjusted to suit the site. If the depth and speed of water permit, the bottom and two or three layers of the sides are lashed or spiked together in the shallows, floated into position, and held there while the first loads of stone are dumped into the box to anchor it.

TRESTLE PIERS

5. **Timber Trestle Piers**. Trestle piers may consist of one or two bends as illustrated in Fig 14-2-4 and 14-2-6. These designs are even bearing for the groundsills and in preventing scour. For use in midstream, a common form of construction is to use piles for the foundation and to cap them just above water level, then the trestle pier is erected on the capsills.

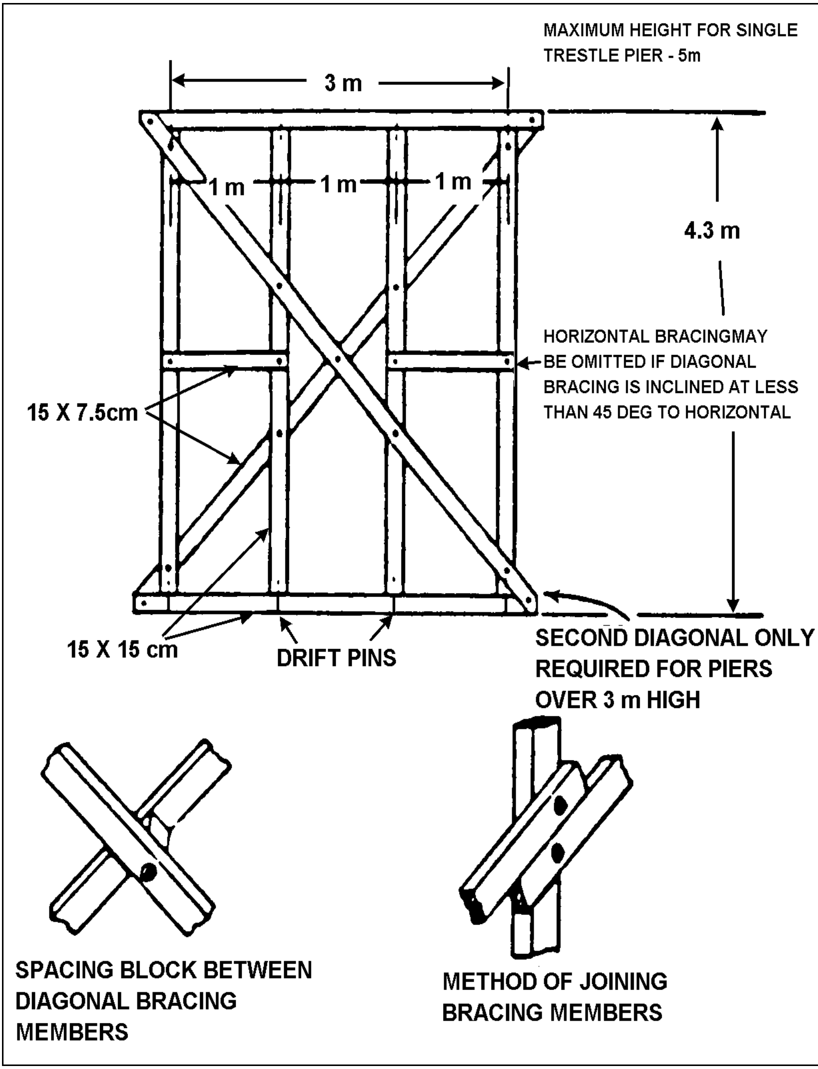


Fig 14-2-4 Example Framed Timber Trestle

6. Design of Timber Trestle Bents.

a. **Legs**. The centre to centre spacing shall not exceed five times the lengh of the capsill. The distance between the outside legs shall not be less than the width of the roadway between ribands. With a squared cross-section, set the legs with the longer dimensions across the width of the bridge. A guide to the capacity of various legs sizes is given in the following table.

Leg Size (mm)		**Maximium Unsupported Height (m)**	**Maximium Load (Tonnes)**
Squared	**Round**		
150 x 150	177	4.6	8.2
150 x 203	203	4.6	10.9
203 x 203	254	6.1	14.5
203 x 254	279	6.1	18.1
254 x 254	304	7.6	22.7
254 x 304	330	7.6	27.2
304 x 304	335	9.1	32.7

Fig 14-2-5 Timber Trestle Leg Sizes

b. **Capsills and Groundsills**. With a squared cross-section, set the longer dimension vertical. The shorter dimension shall not be less than the width of the supporting legs. With round timber, the diameter shall be at least 25 mm greater than the legs.

c. **Bracing**.

(1) For bents less than 1.2 m high, no lateral bracing is required. For bents between 1.2 and 3 m high, lateral bracing is required on one side, and for bents higher than 3 m, brace both sides.

(2) Longitudinal cross-bracing is required in double bent piers for similar heights. In long bridges, at every third pier, all legs of the two bents shall be braced together.

(3) The size of braces is normally 150 mm x 76 mm for piers loads up to 27.2 tonnes. For pier loads between 27.2 and 68 tonnes, 228 mm x 76 mm bracing may be used. For loads over 68 tonnes, bracing shall be 228 mm x 101 mm.

(4) The angle of inclined bracing shall be between 25 and 45 degrees to the vertical. Where two or more layers of bracing is required, a horizontal brace shall be added to form a "Z" brace.

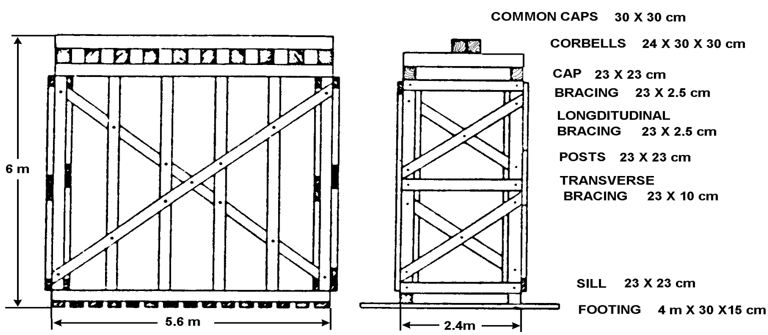


Fig 14-2-6 Example Double Bent Pier

7. **Construction of Timber Trestle Bents.**

a. Accurate cutting of the legs is essential as each must be exact in length and sawn absolutely true at the ends. Unless the operators are experienced, or cutting is done mechanically in a workshop, battens shall be nailed to the timber to guide the saw.

b. The legs are fixed to the groundsill and capsill with drift pins or timber dogs, and the bracing shall be bolted to each leg. If the capsill (or groundsill) has to be made in two lengths,the joint is made over (or under) a leg, and three adjoining timbers dogged together.

c. Bents are constructed on a suitable area of level ground. While the legs are being sawn, the holes are drilled in the capsill and groundsill to take the drift pins. The legs and sills are then laid on the ground in their final relative positions and the sills are windlassed together in two places with steeel wire rope (SWR). The holes for the drift pins are then drilled in the legs and the pins driven home. Meanwhile, holes for the bolts securing the bracing are drilled and the bracing on one side is fixed in position. The trestle is then turned over and the bracing fastened on the other side.

d. If dogs are used, they are only driven halfway and the bracing is not fixed, before turning the trestle over. The dogs on the other side are then driven completely. After fixing the bracing on that side the trestle is again turned over, in order to complete the dogging and to fix the bracing on the first side.

8. **Erection of Trestle Bents**. The mudsills or other foundation are laid first. There is the same necessity here for levelling and drainage as stressed for the construction of bankseats. Trestles constructed of 150 mm x 150 mm lumber can be positioned fairly easily by hand but tackles or a crane will be required for heavier trestles. The two bents of a double bent pier are most conveniently erected separately and then braced together, but if the pier is well braced and not too heavy, the complete pier may be lifted into position by a crane or derrick. When trestles are to be erected on piled foundations in a river, they are best floated out and hoisted into position with the aid of the piling rig.

9. Lashed Trestles. Where only round timber and lashings are available, a bridge for light loads can be made with trestles similar to that in Fig 14-2-6, to which roadbearers are lashed. Points to remember in constructing lashed trestles are:

a. the legs are first lashed to the transom and the ledger, then the trestle is squared up by making the diagonal braces equal before lashing them into position;

b. the position of the ledger relative to the bottom of the legs depends on the nature of the bottom of the gap. If it is mud, the ledger shall be low; if it is rocky, the ledger shall be high enough to clear any obstruction;

c. if the bottom is very soft, shoes of 5 cm planking about 0.4 m^2 can be spiked to the bottom of the legs;

d. lashings shall be tightly made and frapping turns well beaten in. Keep cordage dry until required; wet cordage stretches as it dries out; and

e. lashed trestles can be carried into position if the water is not too deep; otherwise, they can be launched. During such a launch, the trestle is controlled by foot-ropes attached near the ledger-leg junction and spars lashed to the tops of the legs. Foot-ropes can be attached by a draw hitch, the running end of which is temporarily seized to the leg where it will be easily accessible when the trestle is in position. The spars shall be lashed on the inside of the legs so that they can be used subsequently as handrails.

10. After erection, the trestle is strutted upright by spars driven into the bed of the river and lashed to the legs. After the decking of the bridge is completed, each trestle is jumped in by as many soldiers as possible jumping in unison over each transom in turn. The transom is then adjusted to the correct height. To do this, fix a spar over the tips of the legs and suspend two tackles from it to support the loaded transom while the lashings are taken off prior to refitting.

PILED PIERS

11. The round figure bearing capacity of round piles may be taken as 9.1 tonnes per 228 mm pile and 18.1 tonnes per 304 mm pile. In soft river bottoms, the mimium penetration to guard against scour is 3 m. Piles in a pier shall not be closer together than 91.4 cm, centre to centre.

12. It is unlikely that all piles of a bent will be driven exactly true and in consequence, their tops will need pulling into line with the aid of a Pull-lift jack or Spanish windlass, etc. Once in line, stiff horizontal walings

shall be attached and the tops of the piles cut off to the same height, using the walings as guides.

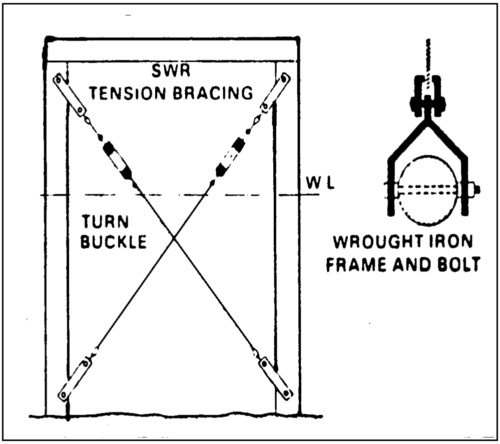


Fig 14-2-7 Diagonal Bracing for Pile Bents Below Water Level

13. Bracing is similar to that for trestle bents. A method of providing diagonal bracing below water level is illustrated above. Before driving, a wire rope fitted with a turn-buckle at the free end is attached at the point near where the pile will project above the ground. After the bent is complete, the free ends of the wire ropes are fixed on the top of the opposite pile and tightened simultaneously by means of the turnbuckles.

14. The panels, transoms, etc, of EWBB (Extra wide Bailey Bridge) used to form piers. The methods of erecting an EWBB pier are set out in manual C-90-108-000/MH-002.

PIERS PARTIALLY DEMOLISHED

15. Fig 14-2-8 shows how demolished piers can be used. The whole pier need not be levelled to the same height; all that is required are level beds for the parts of the crib which constitutes the new pier top. The initial difficulty is getting men and equipment onto the pier. One or two crowbars jammed into holes in the centre of the pier, made with shaped charges or rock drills, will provide anchorage to which ropes or safety belts can be attached.

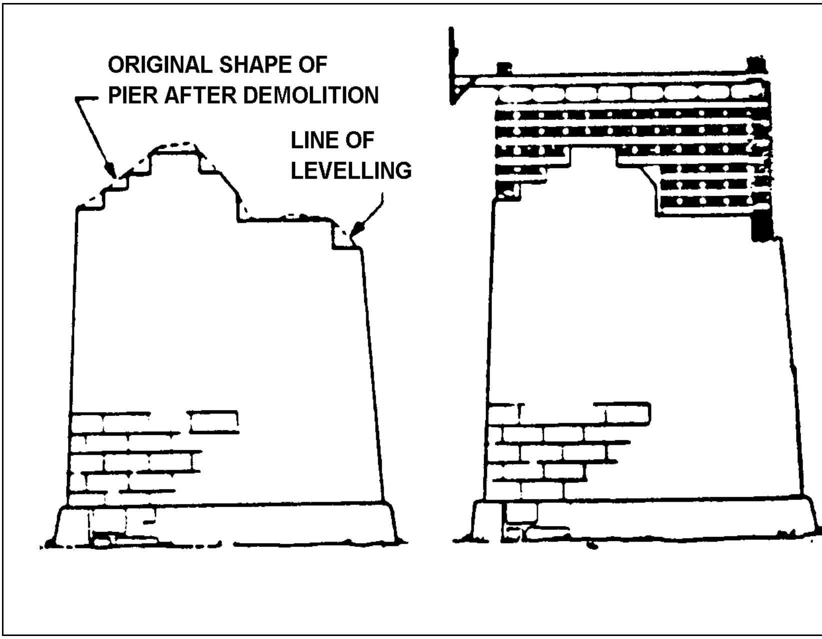


Fig 14-2-8   Levelling the Top of a Damaged Pier

SECTION 3

PILE DRIVING

GENERAL

1. Pile driving is like driving a nail. The essentials elements are a pile suited to the purpose, a means of placing the pile and holding it during driving, a hammer of appropriate weight which is varied to suit circumstances and directed so as to strike the pile squarely, and finally the number of blows required by the hammer. A heavy hammer falling a short distance is more effective then a little one falling a long distance. As a general rule, the best weight of hammer is 1-1/2 to two times the weight of the pile and the drop is not more than 1.8 m. However, the best height will be determined by experiment. The two sorts of piles used in military bridging are bearing piles and sheet piles.

2. **Bearing Piles**. Bearing piles are normally of timber but can be steel casings or concrete and are used to support vertical loads in circumstances where ordinary grillage or mat foundation are unsuitable. The same sort of pile is used in dock work for providing strong anchorages and as dolphins to piers and quay walls.

3. **Sheet Piles**. Sheet piles are used to support horizontal loads imposed by earth or water, as in retaining walls and abutments and to prevent water entering into excavations. Special interlocking steel sections are normally used, but timber can be used as illustrated in Fig 14-3 -1.

4. **Pile Driving Equipment**. Pile driving equipment is described in Chapter 7.

PREPARATION OF PILES

5. **Preparing Timber Bearing Piles for Driving**. Either round or squared timber can be used. The bark is stripped from standing timber before driving. Round timbers are normally driven narrow end downwards unless they are to be driven through very soft soil to hard stratum, where a large bearing area at the foot is required. They are then driven butt downwards.

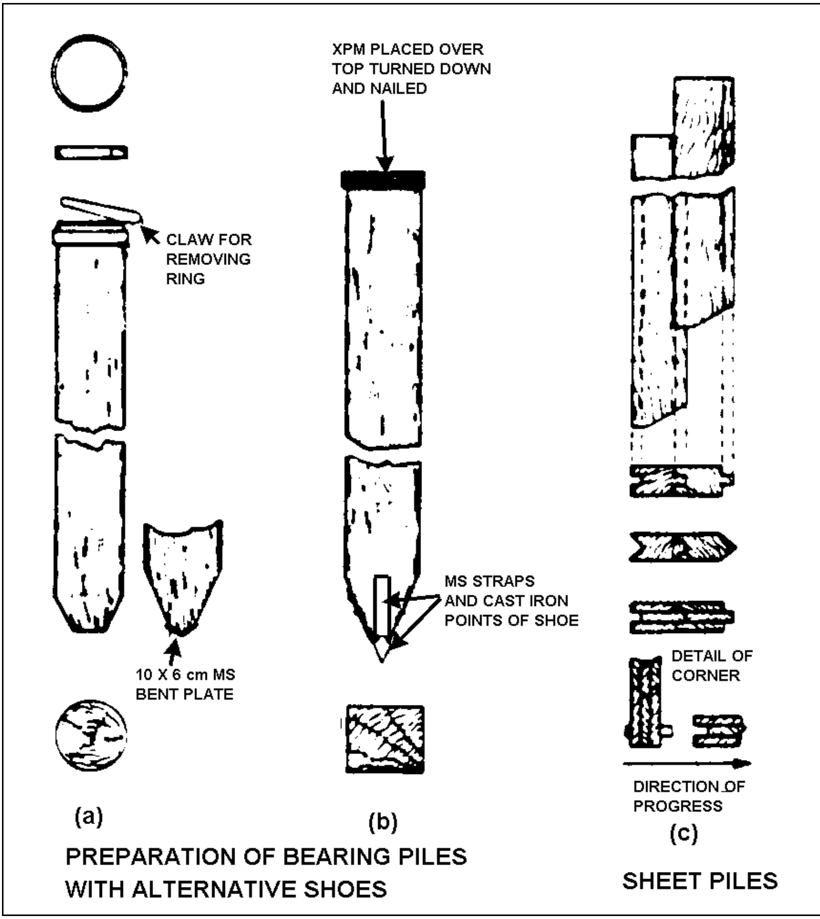


Fig 14-3-1 Typipcal Timber Piles

6. The pilehead shall be prevented from splitting under the blows of the hammer. The conventional method is to shape the head to take an iron ring (Fig 14-3 -1(a)). If speed is essential and a softwood pile is being used, the shaping can be dispensed with and the ring driven on with the first blow of the hammer. Another method is to cap the pile with a layer of expanded pierced metal (XPM) which is nailed to the sides of the pile. The first blow of the hammer drives the mesh into the wood, thereby reinforcing it (Fig 14-3 -1(b). With certain driving rigs, a dolly or follower of hardwood is

interposed between the head of the pile and the hammer and capping the pile is then unnecessary.

7. The foot is usually cut off square and the edges chamfered (Fig 14-3 -1(a)) which is adequate for ordinary soils. If hard driving is envisaged, the foot of the pile is pointed and shod with a steel shoe (Fig 14-3-1(b)). The shoe must be put on perfectly symmetrically, otherwise the pile cannot be driven straight. Piles can, if necessary, be driven in two or more lengths. The first length is driven nearly full length; the head is then cut off truly square, and the second length is butt-joined to it, the joint being made with fishplates of steel or timber, bolted or spiked to the piles. Timber fishplates shall be long enough to permit the leading end to be chamfered for easy driving.

8. **Preparing Sheet Piling.** The heads of sheet piles, both steel and timber, are normally protected from damage by a steel helmet for the particular type of pile or by a hardwood dolly. The feet of timber sheet piles are usually cut off at an angle so that driving tends to hold a pile firmly against its neighbour (Fig 14-3-1(c)).

DRIVING PILES ON DRY LAND

9. **Siting the Rig.** More than half the total time spent in driving piles is devoted to positioning them. Careful thought shall therefore be given to the siting of the rig so as to minimize movement. Fig 14-3-2 shows methods where the ground is level on the line of the piles (a) and where a level position for the rig is difficult to find (b).

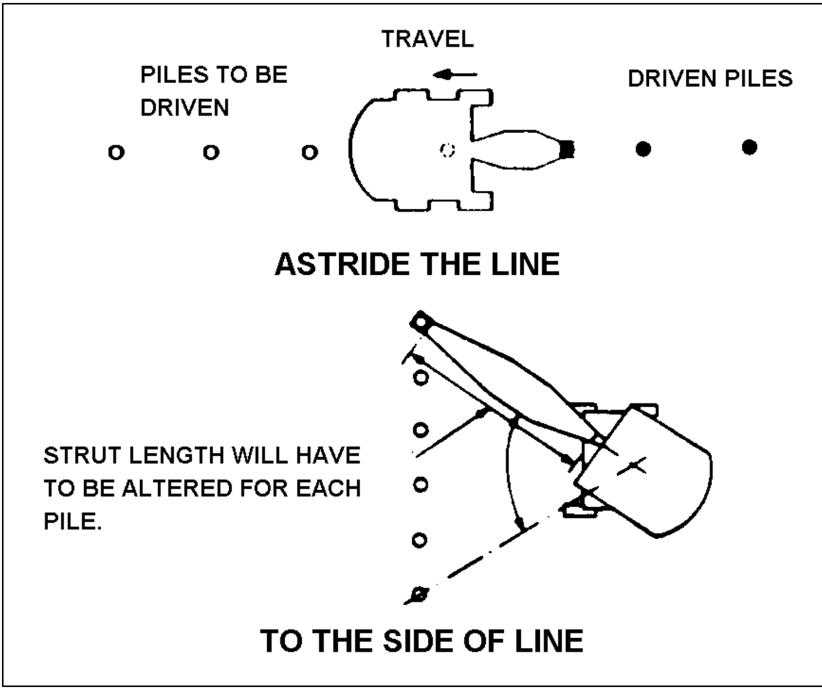


Fig 14-3-2 Positioning a Piling Rig

10. **Positioning the Pile.** The position of the foot of the first pile in a row or group is fixed by direct measurement from a datumpoint. A hole about 0.3 m is dug to receive it, and the pile is then pitched, or up-ended by the winch and tackle of the rig, and fixed in the leads with its foot in the hole. The pile is then plumbed by manipulation of the rig. With squared piles that subsequently have to be braced together, it is essential that the faces are accurately in line, and the guide walings are needed to prevent them twisting during driving. An example of waling, as used for sheet piling, is shown below.

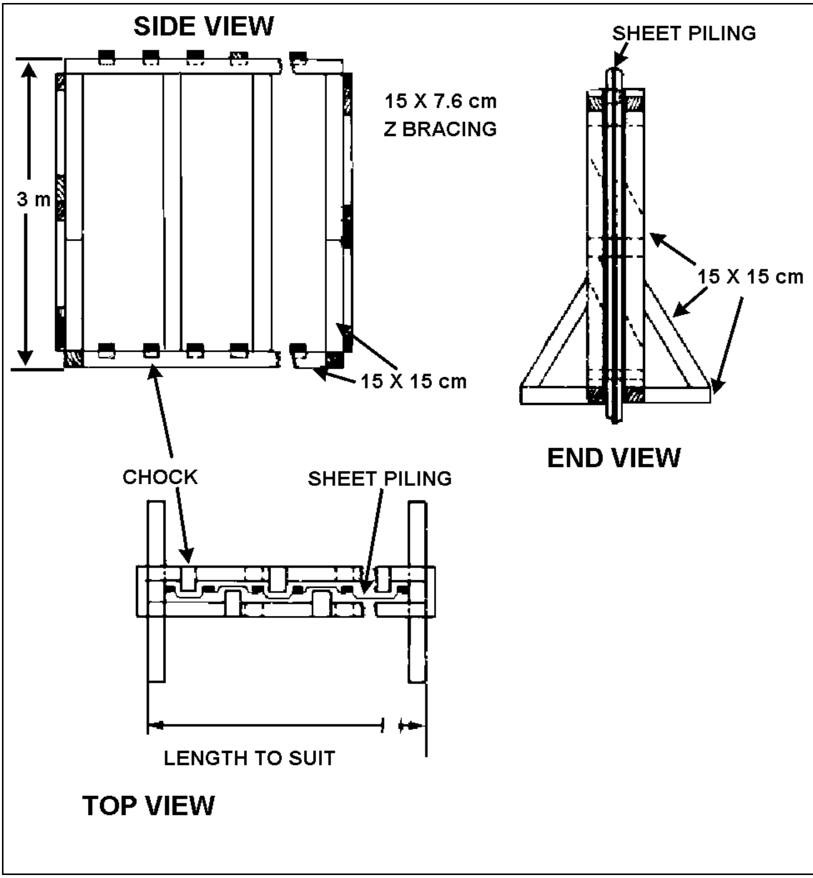


Fig 14-3-3 Waling Frame for 9 m Sheet Piling

11. **Driving**. Once driving has started, the pile shall be driven to its final set. The set is the distance the pile penetrates after each blow. If the pile ceases to penetrate, then driving shall stop so as not to damage the pile. This is caused when the foot of the pile reaches a hard stratum, or when the sides of the pile and the ground cause too much friction, or a combination of both. The final set, which is normally taken as the average for the last five (or sometimes ten) blows of the hammers, shall never be less than 0.5 cm. A method of measuring set is shown in Fig 14-3-4.

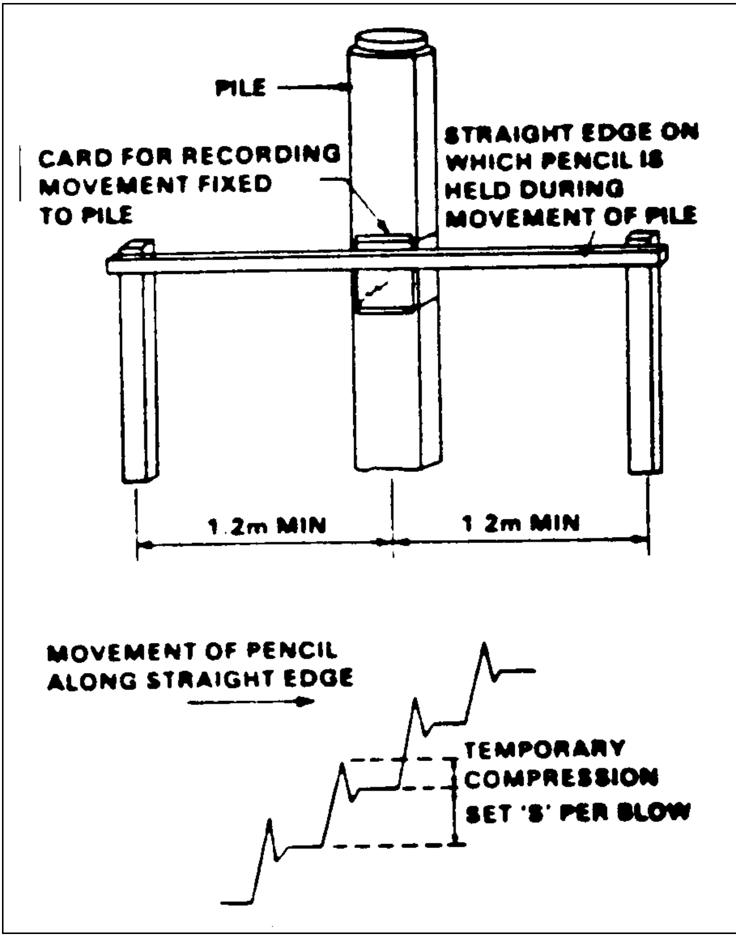


Fig 14-3-4 Measuring the"Set" of a Pile

DRIVING BEARING PILES IN WATER

12. There are two methods of driving piles in water: the first is to mount a normal rig on a raft or barge which is anchored out in the stream (the floating rig method) or alternatively to cantilever out from part of the bridge already built (cantilever pile driving). The selection of method and detailed design are outside the scope of this manual. Three ways of positioning piles for driving with a floating rig are illustrated in Fig

14-3-5. The method of pitching the piles depends on the current, the size and stability of the raft, and the experience of the crew.

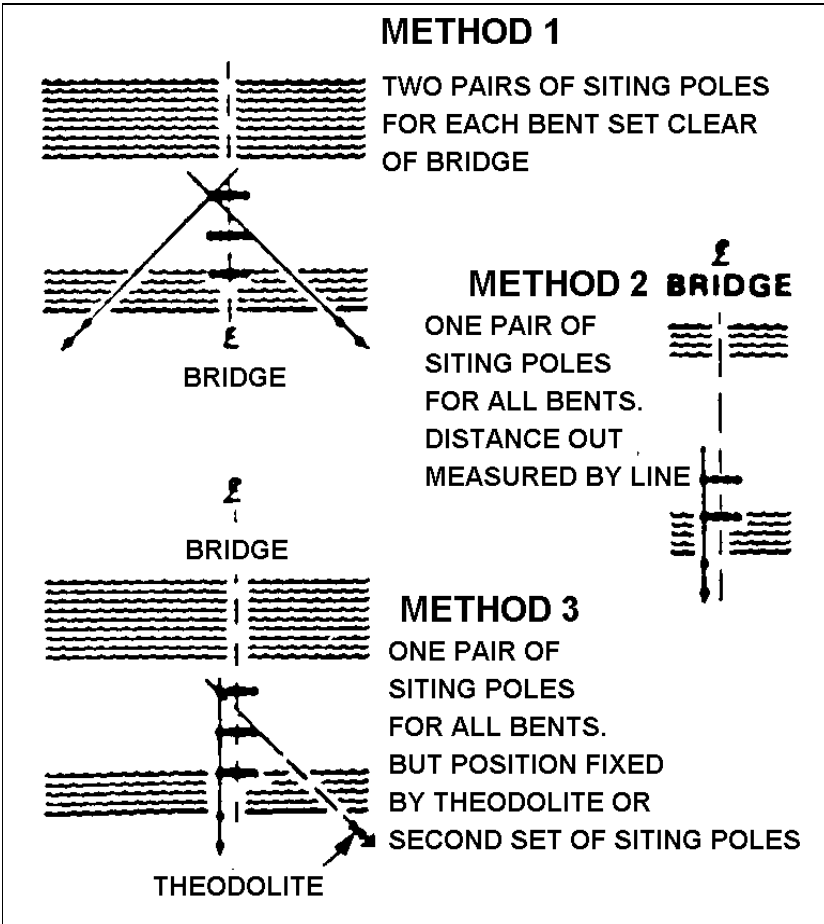


Fig 14-3-5 Positioning Piles in Water

DRIVING SHEET PILES

13. Sheet piles may be either steel or interlocking types (Fig 14-3-6), or of timber as shown in Fig 14-3-1. Steel sheet piles are included in engineer stores, while timber sheet piles are made up for the particular job

at hand. Interlocking sheet piles are driven with the male portion of the clutch leading; otherwise stones may become jammed in the female portion.

14. It is normally economical to drive sheet piles in pairs and helmets for this are usually available. To prevent creep and subsequent leaning of the outer pile, sheet piles are usually driven in panels of 10 to 15 pairs of piles as illustrated in Fig14-3-6.

15. Guide walings are necessary when positioning the piles. If a pile frame (leads) is being used, guide walings are only necessary at ground level. If a double acting steam hammer suspended from a crane is providing the power, upper guide walings are required between 3 and 6 m above ground level depending on the length of piles. Fig 14-3-3 shows a typical waling frame for a 9 m steel sheet pile.

a. FIRST AND LAST PAIR DRIVEN TO HALF PENETRATION

b. 5th, 4th, 3rd, 2nd AND 1st PAIRS DRIVEN TO FULL PENETRATION IN THAT ORDER

c. SECOND PANEL THREADED ON TO LAST PAIR OF FIRST PANEL AND LAST PAIR OF SECOND PANEL DRIVEN HALF WAY

d. LAST PAIR OF FIRST PANEL AND ALL EXCEPT LAST PAIR OF SECOND PANELS DRIVEN TO FULL PENETRATION. THIRD PANELS THREADED ON AND PROCESS REPEATED AS PER c.

Fig 14-3-6 Sequence of Driving Sheet Pile

16. To pitch and interlock a pair of piles before driving requires a crane capable of lifting the head of one pile to a height at least twice the length of each pile. If the crane is unable to handle long lengths, or if they are not available, sheet piles can be driven in short lengths as shown in Fig 14-3-7. Alternate pairs are driven to different levels and the second tier is then pitched, the joints being welded. The piles must vary in length so that the joints are staggered.

17. If a pile meets hard resistance, it can be left while the adjacent piles on both sides are driven to full depth. The former pile, now being secured on both sides, can be driven more fiercely without the risk of it deviating from its course.

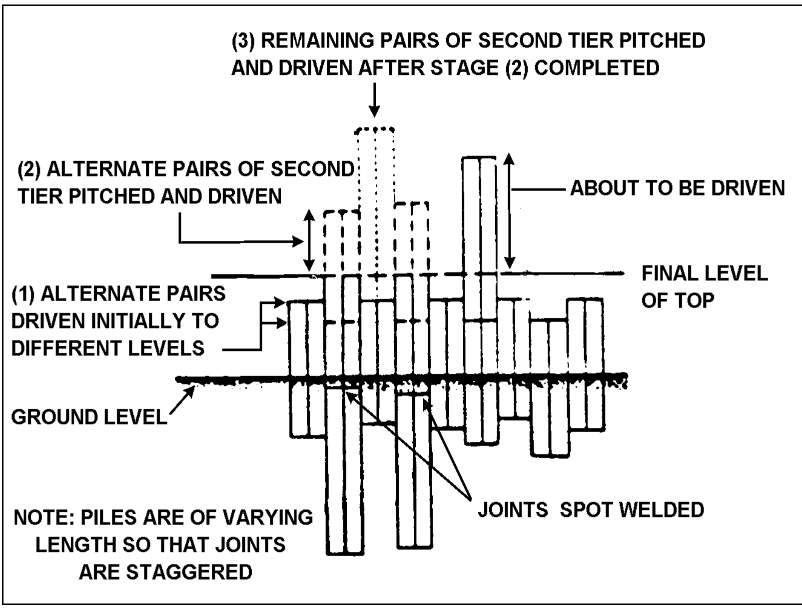


Fig 14-3-7 Sequence of Driving Sheet Piles iN Short Lengths

IMPROVISED PILE DRIVING

18. Short piles, not exceeding 6 to 8 m, can be driven by improvised methods, provided that a suitable hammer can be found. Fig 14-3-8 shows two methods.

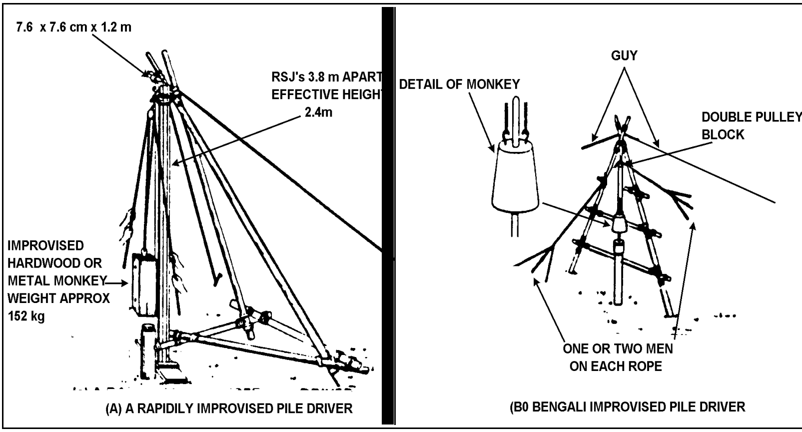


Fig 14-3-8 Improvised Pile Drivers

SECTION 4

BRIDGE CONSTRUCTION AND MAINTENANCE

LAUNCHING METHODS

1. **Cantilever Methods.** With the cantilever methods, lengths are added to the span (which is built on rollers on the bank) to form a nose or a tail or both, and a counterweight may be added to the tail. The whole structure is then either pushed or pulled out over the rollers until the span proper reaches the correct position. The nose and tail are then dismantled and the span is finally jacked down on to the permanent bridge seats.

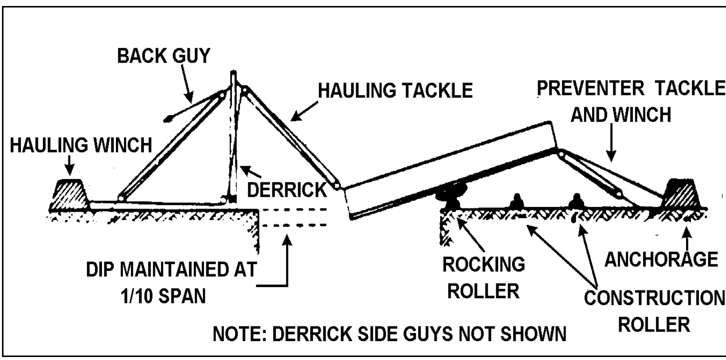


Fig 14-4-1 Launching by Derrick and Preventer Method

2. **Derrick and Preventer Method.** This is shown diagramatically in Fig 4-4-1, and can be used for a complete span or for single girders. When several girders are to be launched singly, they are normally launched in the same vertical plane and then skidded sideways on greased packing to their final positions.

3. **Temporary Bearers Methods.** This is the method commonly used for the girders of a deck bridge. Comparatively light bearers of timber or steel are put across the gap by hauling on ropes attached to them, and the girders are then passed over on rollers of timber or piping supported on the temporary bearers. As a general rule, RSJs are rolled over on their side and then turned upright. A modification of this technique, incorporating the cantilever principle and useful for launching RSJ roadbearers is shown below.

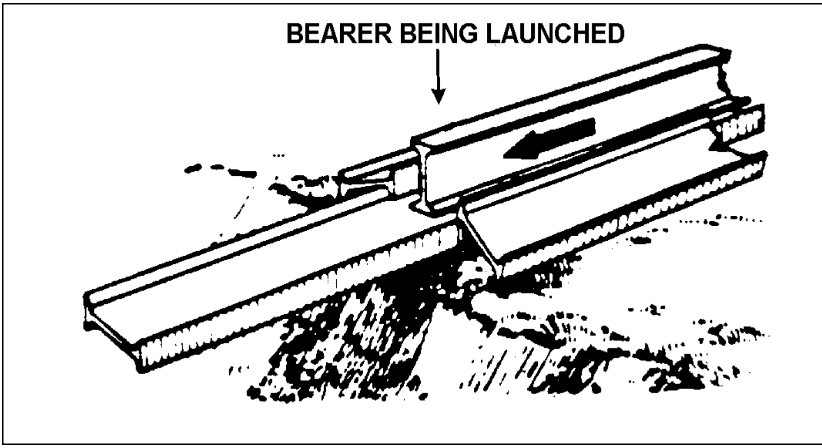


Fig 14-4-2 One Method of Launching Roadbearers

ROLLERS

4. The layout of rollers is included in the launching plan. This specifies the types of rollers to be used, the level at which each set of rollers will be installed, and the distances betwen various sets. The positioning of rollers is always done with great accuracy to ensure a smooth launch. The following points merit special attention:

a. the level of each roller shall be accurately set out. A field level may be sufficiently accurate, but for some tasks an engineer's level and rod will be necessary;

b. each set of rollers will have their axis exactly aligned at right angles to the centre line of the bridge;

c. the foundations of each roller shall be such that there is no chance of even slight settling. Drains may have to be dug if the ground is wet;

d. rollers shall be securely fastened so that they cannot be shifted or overturned as the load moves onto or over them; and

e. rollers shall be properly maintained and inspected before use. The surface shall be free of paint and grit and the bearings clean and well greased.

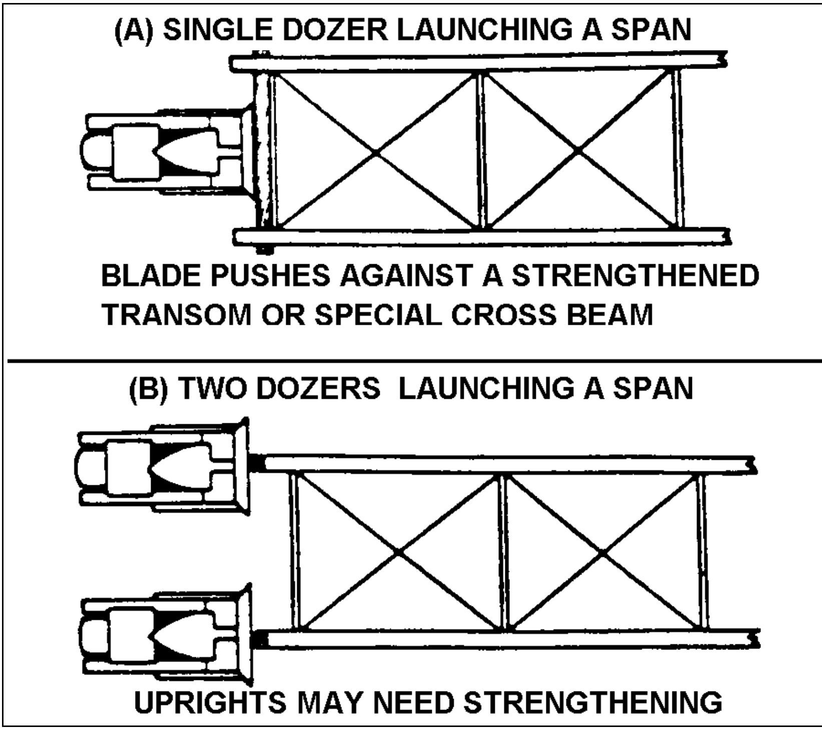


Fig 14-4-3 Launching with Dozers

CONTROL OF LAUNCHING

5. Dozers may be used for launching as shown in Fig 14-4-3. Labourers can also be used if the structure is kept light and the launching plane is horizontal or downhill. Soldiers can act as a readily adjustable counterweight. Winches are used as preventer tackles to assist the labourers, particularly in downhill launches. To avoid any risk of slewing the span, two tackles are used, one on each outer main girder. Winches can be power or hand operated. Fig 14-4-4 shows how the winch rope attaches to the span. When a winch is used as a preventer tackle for a downhill launch observe the following:

a. great care is required to control the brake;

b. the winch rope shall always be paid out under power and the brake applied before the clutch is released;

c. the winch shall be securely anchored; and

d. sometimes, as an additional precaution, a standby preventer tackle is used in conjunction with the winch.

6. Before movement starts, the Bridge Commander arranges for a thorough inspection of all rollers, attachments, blocks and tackles, anchorages, etc, and assigns observers to danger points. The Bridge Commander is the only person to give orders to move the bridge. Observers stationed at danger points may shout orders to stop movement but not to re-start it. The Bridge Commander is placed to see and be seen; but even so, sometimes it is difficult for the Bridge Commander to exercise direct control over all winch operators. In that event, subordinates are placed where they can receive orders clearly and relay them to operators by word or signal.

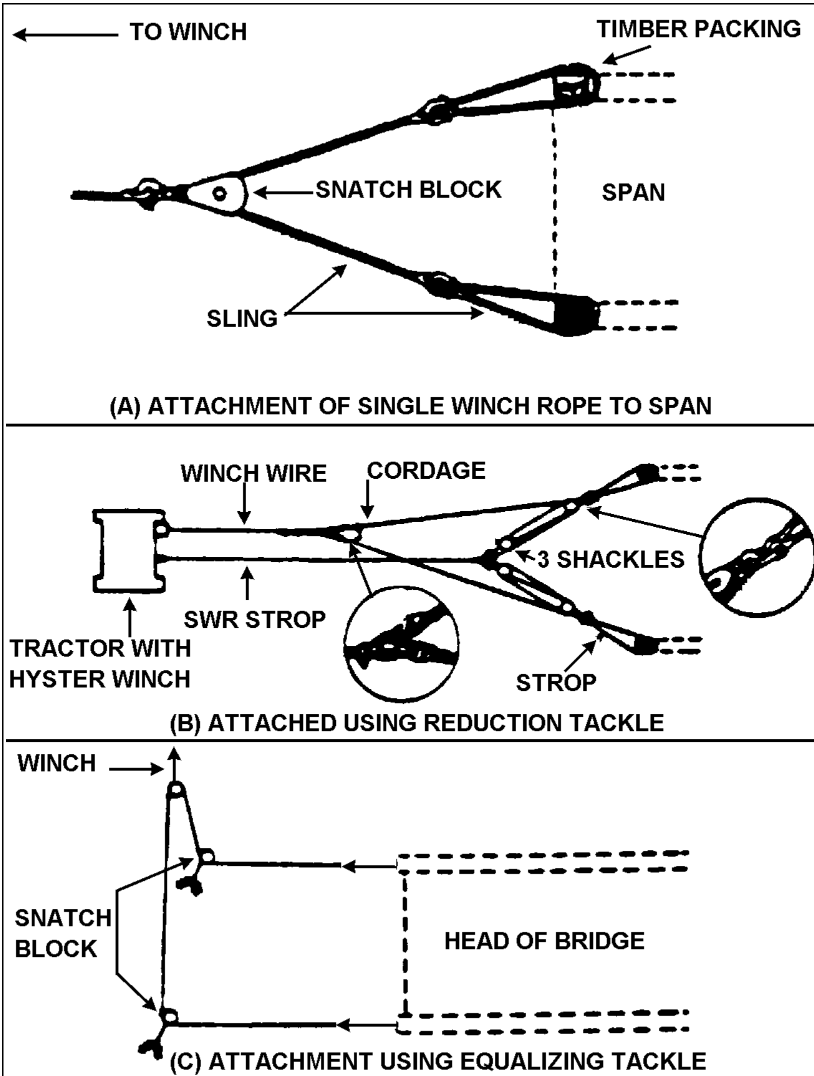


Fig 14-4-4 Launching Tackles

JACKING DOWN

7. The following points shall be observed when jacking down:

   a. only one end of the bridge at anytime may be supported on jacks;

   b. when jacking down a bridge on a slope, preventer tackle shall be rigged and tightened before the load is taken on the jacks;

   c. with a heavy bridge, the two ends are jacked down alternatively, so that the difference in height does not exceed 30 cm;

   d. jacks shall always be positioned under a vertical member and on a substantial foundation;

   e. if the load is too great for one jack, or the girder member will not stand up to the concentrated load at the jacking point, the load is distributed with a jacking beam, as shown in Fig 14-4-5;

   f. the jacks under both sides of the bridge must be operated in unison, so as to maintain the equally distributed load. Experience has shown that no more than four jacks can operate in unison;

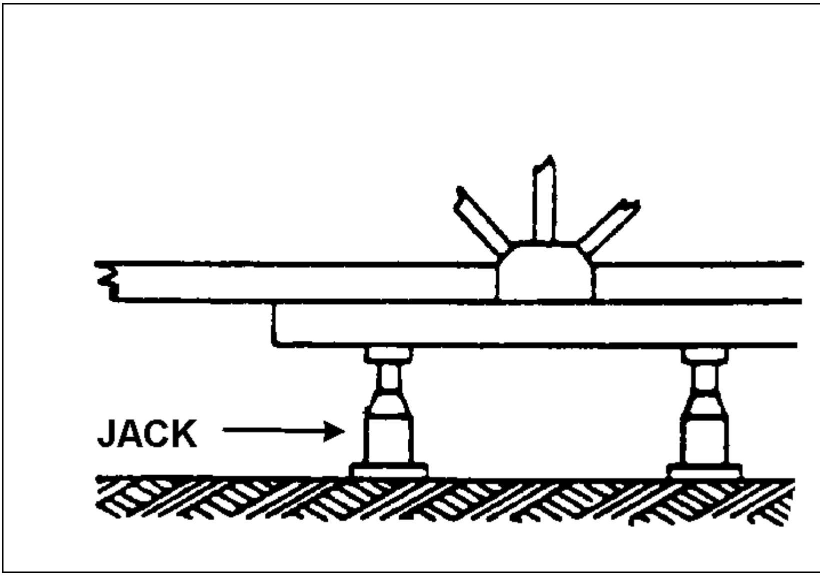


Fig 14-4-5 Distributing a Jacking Load

g. before jacking starts, an ample supply of packing (bridging cribs or squared timber in random lengths and in thickness from 5 cm to 30 cm) shall be available;

h. jacks shall not be operated or held under load unless there is packing to within 5 cm of the underside of the girder below the nearest practicable vertical member;

j. if the ratchet and lever type of jack is being used, it is essential that all jacks required to operate together are of the same make. Different makes have different pitch on the ratchet and this can result in uneven distribution of load; and

k. in jacking down with hydraulic jacks, the release valves shall operate at exactly the same moment. With the jack at rest, the functioning of the valve is liable to be delayed owing to friction. To avoid this, give one or two pump strokes before releasing the valves.

USE OF CRANES

8. A crane may be used as the derrick in the derrick and preventer method described earlier, or for short spans to pick up the girders and place them directly in position. In addition to its normal use in handling the heavier components during building, a crane can be used during the actual launch as a counterweight and then effect rapid dismantling of the tail to permit jacking down to start.

SUPERSTRUCTURE

9. A typical section of a deck bridge is shown in Fig 14-4-6. The bridge consists of roadbearers (in this instance RSJs) and the superstructure, namely all those parts supported on the roadbearers. In a through bridge, the roadbearers are supported by a series of transoms, the ends of which rest on the bottom members of the two girders. These short roadbearers are sometimes referred to as stringers.

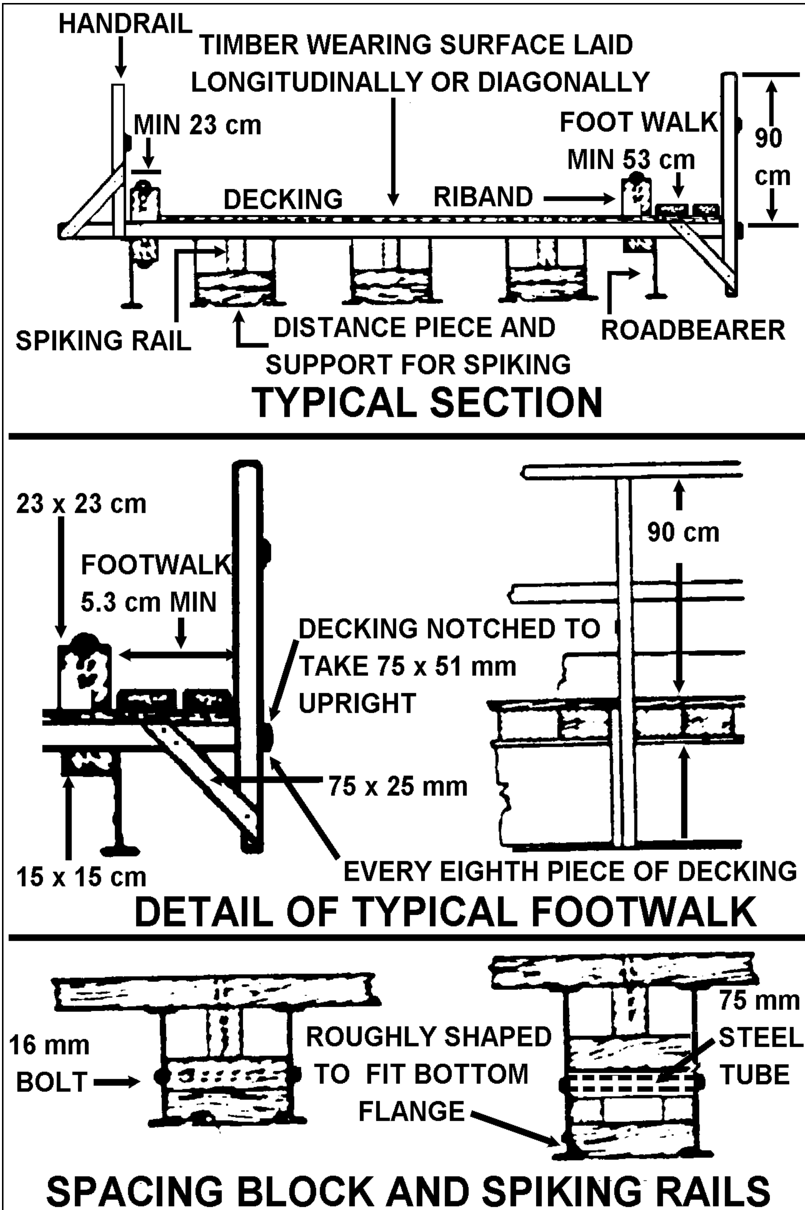


Fig 14-4-6 Typical Details of a Deck Bridge

10. Where spans meet on a single bent pier or transom, the roadbearers are either staggered or laid slightly skewed so that they overlap on the pier. In equipment bridges where positioning stops or cleats are provided, bearers are normally butted.

FIXING ROADBEARERS

11. Roadbearers shall be secured against end movement, sideways movement, overturning, and in case of long RSJs, whipping or lateral movement (Fig 14-4-6 and Fig 14-4-7).

12. **End Movement**. On bankseats this is prevented by the end dam. Where roadbearers overlap on intermediate piers or transoms, they are spiked or welded to the bridge seat or transom depending on whether it is timber or steel. Steel roadbearers shall be fixed at one end only to allow for expansion and contraction.

13. **Sideways Movement**. Spiking or welding will prevent sideways movement but neither is required if spacing blocks are used to prevent overturning.

14. **Overturning and Whipping**. Spacing blocks are fixed at intervals which shall not exceed twenty times the flange width of the RSJ. When fixed with bolts as in Fig 14-4-6, the holes are drilled before the RSJs are put in position.

15. **Logs as Roadbearers**. When logs are used as roadbearers, the underside shall be sawn as shown in Fig 14-4-7(e) to provide a level bearing on the bridge seat or transom. To avoid undue reduction in the strength of the roadbearers, the cut shall not be more than a quarter of the diameter. The log is then fixed with a drift pin.

FIXING THE DECKING

16. Every piece of decking shall bear evenly on the roadbearers. If rough timber is being used, it is trimmed before fixing. A gap of about 6 mm is left between each piece of decking to facilitate the clearance of snow and mud. A nail or spike placed between the planks before they are fixed serves as a handy guage.

17. Each piece of decking shall be nailed or spiked to roadbearers or spiking rails at intervals of not more than 1.2 m. When the roadbearers are RSJs, the spiking rails can either be fixed on top of RSJs as shown in Fig 14-4-7 or between them as shown in Fig14-4-6. The width of spiking rails shall be approximately the same thickness as the thickness of the decking and when placed between roadbearers, it will be one-and-a-half to twice as deep as it is wide.

18. If deck planks are not long enough to cover the full width of the road, two pieces shall be used butt-jointed over a roadbearer or spiking rail. If rough timber has been used for decking, the worst of the projections on the surface shall be removed by adzing.

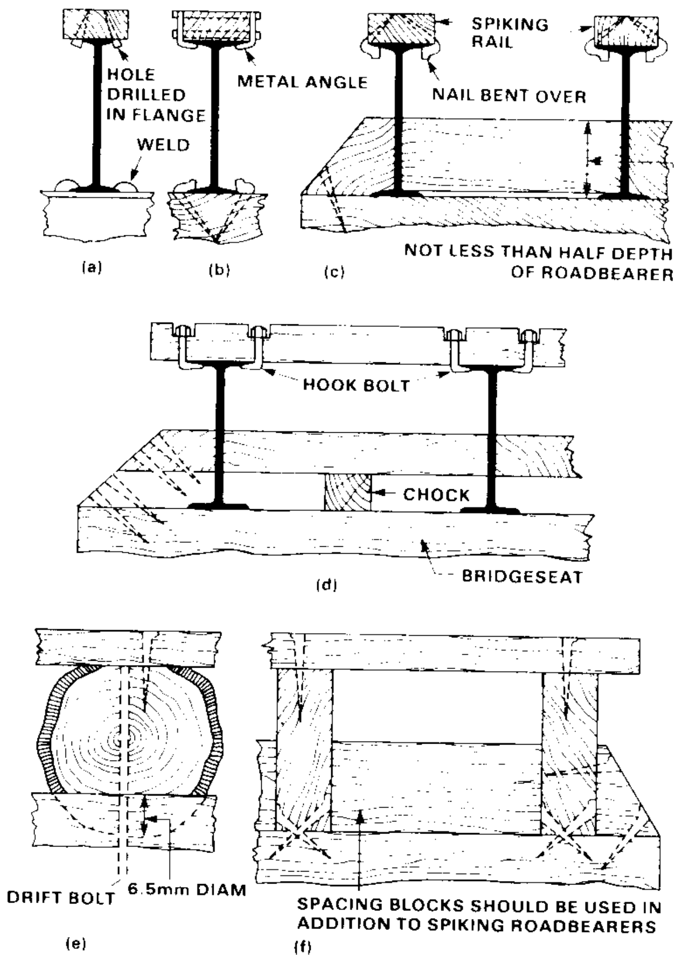


Fig 14-4-7 Methods of Securing Roadbearers and Decking

FIXING TIMBER WEARING SURFACE AND RIBANDS

19. The wearing surface consists of 30 to 40 cm planks laid diagonally or longitudinally over the whole width of the bridge and is nailed to the decking. If there is a shortage of planking, it may be laid along the bridge as wheel tracks only.

20. Ribands may be either bolted as shown in Fig 14-4-6 or spiked to the decking. In both cases the minimum length of riband shall be 3 m and intervals between fixings about 90 cm.

GENERAL MAINTENANCE

21. Bridge maintenance covers the preservation of the bridge from wear and tear due to traffic and weather, and the repair of minor damage caused by hostile action. Normally all floating bridges and selected fixed bridges have permanent maintenance parties. Other bridges are inspected regularly and required work is carried out by normal work parties.

22. Many bridges have to be opened to traffic as soon as possible, and certain tasks that can be left until later are then handed over to the maintenance party to complete. Such jobs may include the completion of footwalks and sign-posting, the provision of driving aids, and the protection of the bridge ends.

23. **Driving Aids**. The end of bridge can be defined by painting the ends of the main girders of a through bridge with white or yellow paint. On a deck bridge, the end posts of the handrails can be similarly treated. The limits of the roadway are best marked by a broken line painted white on the top of the ribands, 60 cm of painted length at 120 cm intervals is suitable. Some equipment bridges include driving aids or can be fitted with supplementary driving aids, for example medium girder bridge. To help drivers keep to the required 30 m nose to tail spacing, the approved symbols will be fixed at 30 m intervals.

24. **Protecting the Ends of Bridge**. The ends of main girders (and handrails of deck bridges) can be protected by stout posts, of 20 cm timber or two lengths of rails wired together, fixed firmly in the ground about 90 cm from the girder and standing about 120 cm high, painted white. The ends of ribands are best protected by adding lengths splayed outwards to form a funnel end for the traffic to drive into. The end of the decking where

it joins the approach road is best protected by keeping the approach road surface about 3 cm above the decking. This needs regular attention as the traffic tends to form a hollow here.

MAINTENANCE TASKS

25. The detail of tasks depends on the type of bridge, the form of construction, the intensity of traffic and climate conditions, and is usually incorporated in the orders for the commander of the bridge maintenance party. Some applicable tasks are:

a. **Decking**. Repair and replace the wearing surface, remove mud and de-ice in winter;

b. **Movable Bearings, Expansion Joints**. Keep clean and greased;

c. **Joints and Fasteners**. Tighten nuts on bolts, look for loose rivets, and check tension in bracing rods;

d. **Bridge Seats**. Check for level (change may be due to settlement caused by scour at foundations of piers, blocked drainage at bankseat); and

e. **Floating Piers**. Keep piers dry by pumping and patching, and watch for chafing and wear on anchor cables, and dragging anchors.

PROTECTION AGAINST FLOATING MINES, DEBRIS AND ICE

26. Debris and ice are a danger to piers, particularly floating piers. They can puncture boats and pontoons, and collect around piers and anchor cables causing the latter to break or anchors to drag. The increased water pressure due to debris around fixed piers can shift them from their foundations.

27. **Booms**. A boom is an obstacle placed across the river which prevents floating objects from reaching the anchors and bridge. Each boom is designed for a particular condition of current and bank and for the floating object. Thus, the complete protection of a bridge may consist of a

series of booms, one against floating mines, one against swimmers, and one against flood debris. However, the primary requirement, for any boom is secure anchorages. Fig 14-4-8 shows a simple boom which is effective against surface debris. Deep floating mines and waterlogged boats may however ride under it.

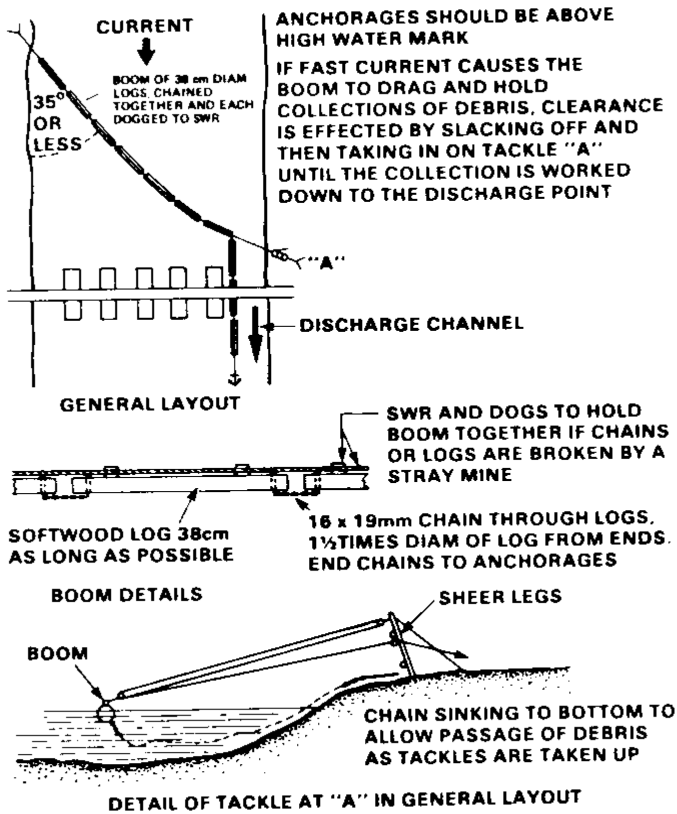


Fig 14-4-8 Log Boom

28. Another easily made boom is the concertina boom illustrated in Fig 14-4-9. This should hold up most types of mines and debris as well as being an obstacle to swimmers. The debris accumulates however and the boom must be swung to the bank periodically for cleaning. Therefore two booms are required, one in action and one being cleaned.

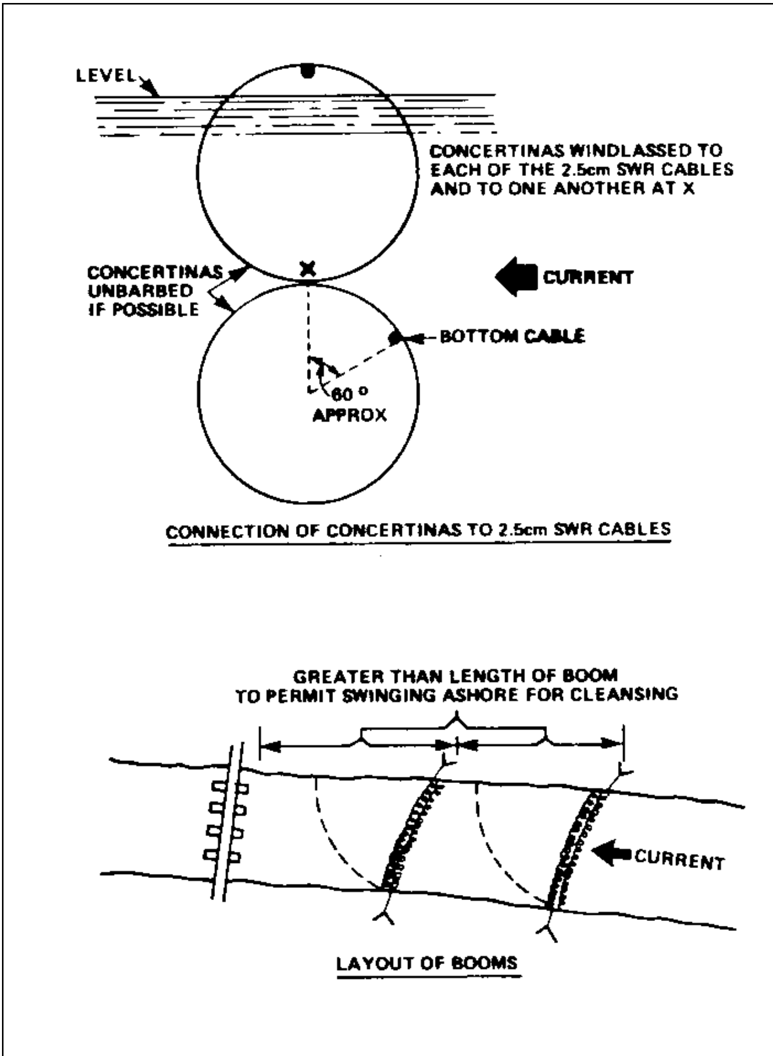


Fig 14-4-9 Concertina Booms

29. **Cutwaters**. A cutwater is usually a floating triangular structure anchored just above the anchor cable or the pier which it protects. It is designed to divert floating debris through the water gap between the piers. In shallow water, a cutwater may be built on piles.

30. Bridges require extensive protection against ice. Ice flows may hit and cause considerable damage, and ice dams, up and down-stream can impound water create flood conditions at the bridge. The protection of a pier is usually provided by an ice breaker as illustrated in Fig 14-4-10. The steel cutting edge slopes from above the highest water level to below the lowest expected level. The ice rides up the ramp, breaks under its own weight and slides off the tent-shaped top into the waterways on either side of the pier.

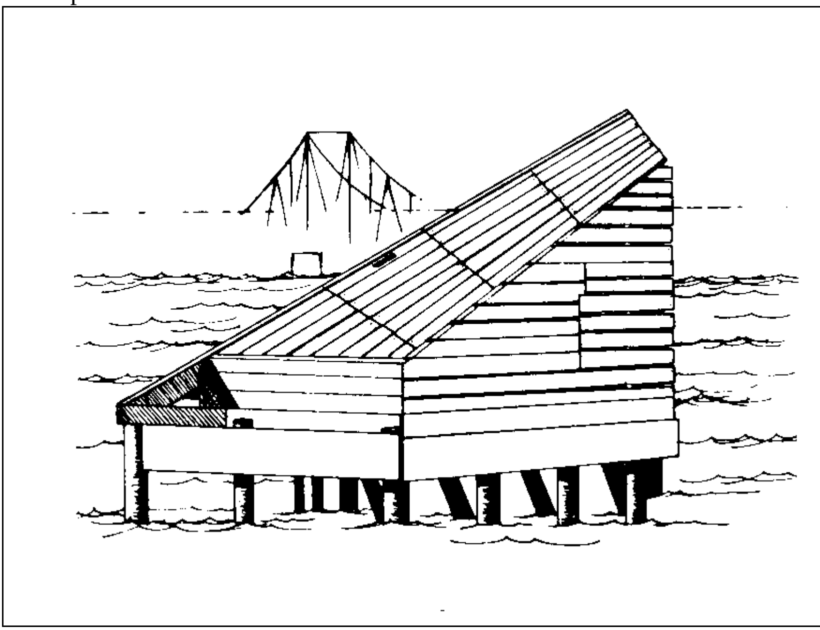


Fig 14-4-10 Completed Ice Breaker

ANCHORAGES FOR FLOATING BRIDGES

31. There are several methods of securing a floating bridge. Methods include anchors, shore lines and standing cable, or by bridging boats. A combination of any two or more methods can be used as required. The design of buried, surface and elevated anchor systems is covered in B-GL-320-005/FP-001.

32. Two types of improvised heavy-duty anchors made from Bailey Bridge panels, namely the panel with flukes and the panel box anchor, are

described in C90-108-000/MH-002. Anchors can also be made from other materials, for example, a sunken vessel filled with ballast makes a very strong anchorage.

33. **Laying Box Anchors**. A box anchor made from Bailey panels and filled with hardcore or stone weighs between 4.08 and 5.4 tonnes. If a suitable civilian buoy-laying vessel is not available, a special raft is required. The anchor can be constructed and filled on the bank and then pushed out over rollers (and a short pier if necessary) onto the deck of the raft. It can either be suspended from a gantry built centrally over the gap between the pontoons and lowered into position or held on a platform of rollers and then pushed over the end of the raft.

34. The gantry method is used when very accurate positioning is required. This also lessons any risk of the anchor cable and buoy being caught up with the box as it tips over. When launching over the end of the raft, the box anchor must be securely lashed to the deck during passage to the site. Frequently, two or three anchors are built concurrently and carried together on the raft for laying. The waiting anchors shall be secured because of the violent movement caused to raft when launching.

35. Anchor cable, with the free end buoyed so it will reach the surface, is fixed to the anchor and launched with it. These buoys are painted with a number corresponding to the pier to which it will be connected. When connecting the anchor to the pier, the main anchor cable, which will probably be 30 to 60 mm SWR, is best carried on a reel on a power boat or second raft. The procedure starts by shackling the free end to the buoyed cable and ends when the other end of the cable is transferred to the pier winch.

36. In very strong currents, anchor cables may be attached to the superstructure of the bridge in order to avoid the downward drag of the cable on the pier's bows. This will also be done if false bows have been fitted. The anchor cable is usually passed round a single pulley block secured to the superstructure so that it can be led back to the winch. Both launching raft and cable craft shall be equipped with their own anchors for emergency use.

SHORE LINES

37. Shore lines are used whenever possible instead of anchors, the limiting factor being that the angle that the line makes with the centre line of the bridge must not be less thasn 45 degrees. The anchorage is first prepared and then the end of the line is attached to it. The other end is hauled to the pier using the pier winch and pilot lines as required. A separate anchorage is normally provide for each line so that a direct hit by bomb or shell will affect only one line.

SECTION 5

IMPROVISED WATER CROSSING DEVICES

PERSONNEL WATER CROSSING DEVICES

1. **Trouser Float**. If soldiers are unable to swim, they can cross a water obstacle by using a simple flotation device made from a pair of trousers.

a. First both legs are knotted or tied off securely as close to the end ofthe legs as possible and the front zipped up. Next the trousers are thoroughly wetted and the legs filled with air. This is done by grasping the trousers by the waist band, holding them high over the head and slapping them down hard on to the surface of the water. If less noise is desired when the trousers are filled with air, they should be wet and held out front at arms length when the soldier jumps into water of reasonable depth.

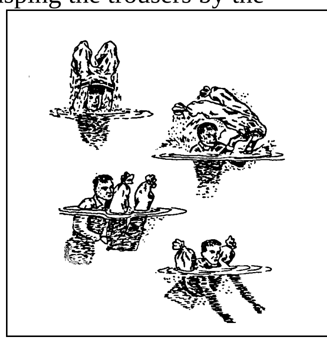


Fig 14-5-1 Trouser Float

b. The length of time the trouser float is effective is determined by the tightness of the trouser leg knot and the condition of the trousers themselves.

2. **Gasoline Can Raft**. Empty gasoline cans can be tied together to form any size of raft or waterwings. For waterwings, two cans should be lashed together with a short lashing and the swimmer lies between the two. A raft is constructed by lashing the cans to a light framework of saplings or bamboo. It may be used for personnel or equipment may be put on it and push the raft across by swimming. For calculating the load capacity of the raft, use a figure of 15 kg per can. For example, a six can raft (Fig 14-5-2) has a load capacity of 90 kg. Construction time for two soldiers is approximately 20 minutes. Equipment required is:

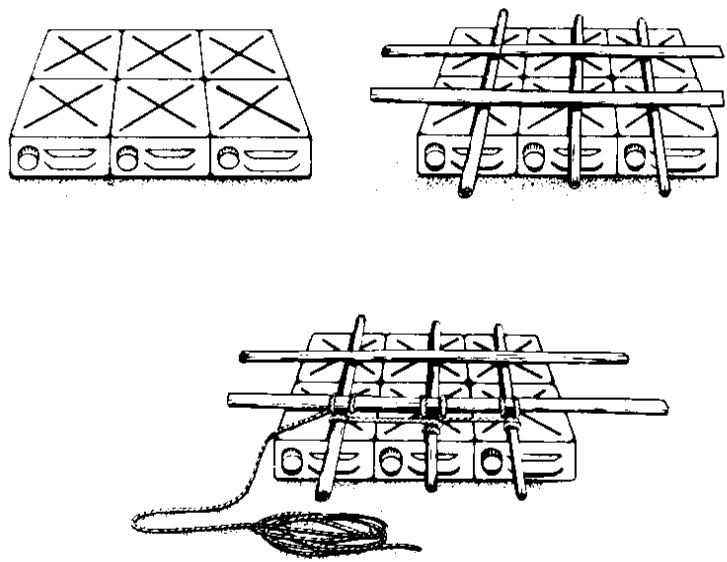


Fig 14-5-2 Six Can Raft

a. six gasoline cans;

b. two 10 m lashings; and

c. one hand axe or machette.

3. **Empty Boxes**. A single box or two boxes lashed together to form waterwings will provide adequate flotation to transport personnel across a stream. The size and type of lumber as well as the condition of the boxes themselves will determine the amount of effective flotation they provide. Ammunition boxes are a very satisfactory expedient and are normally available.

4. **Brush Rafts**. Brush rafts can be constructed quickly, producing very effective two or four person rafts. The raft is constructed by laying out

a 5/4 ton vehicle tarpaulin. Brush is then gathered and tied into 50 cm diameter bundles and placed on the tarpaulin. The sides and the ends are then folded over the bundles and tied by cordage. The raft size should be 2 m x 1.75 m x 0.5 m. This raft will hold two soldiers, plus their equipment and is paddled or pushed across the stream. Construction time for two soldiers is approximately 15 minutes. The material required is:

a. 5/4 ton tarpaulin;

b. hand axe or machette;

c. paddle or long push pole; and

d. small lashings.

A larger brush raft can be constructed by using a MLVW tarpauline with a capacity of 1100 kg. It is constructed in the same manner to form a 3 m x 2.5 m x 0.6 m raft.

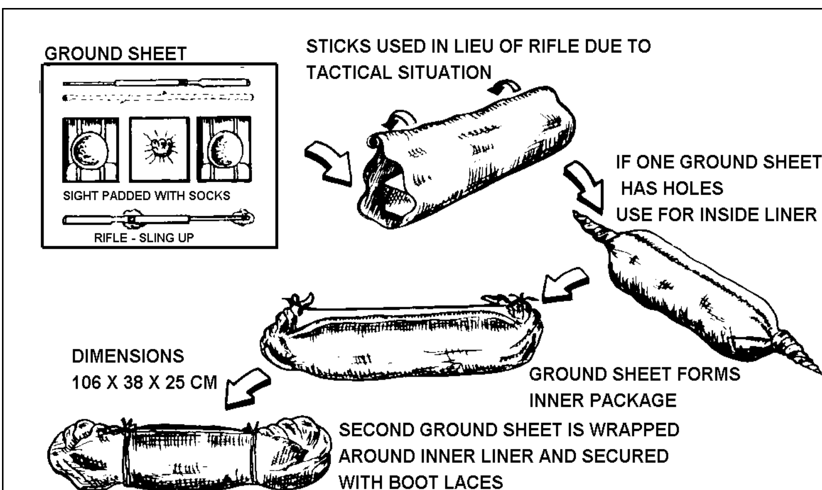


Fig 14-5-3 Gound Sheet or Poncho Raft

5. **Ground Sheet (or Poncho) Raft.** The ground sheet (or poncho) raft can be constructed very easily from the personal equipment of two soldiers and is capable of supporting 36 kg (Fig 14-5-3). The ground sheet (or poncho) is laid out on the ground and the weapons (or sticks if the

weapons are to be left out) placed 50 cm apart on the poncho with the butts facing opposite directions. The packs or webbing are then placed between the weapons with helmet and liner on the top of each. The remaining personnel equipment (boots, clothing, etc) is placed between the packs. Next the ground sheet (or poncho) is zipped up and the loose edge rolled in a tight roll until the ground sheet (or poncho) is wrapped tightly around the equipment. Then both ends of the ground sheet (or poncho) are twisted tightly and pulled over the bundle and tied with a boot lace. The second ground sheet (or poncho) is wrapped over the first in the same manner and tied with a boot lace. To make the raft more stable, two more boot laces are tied around the centre of the raft. Two non-swimmers can cross a stream by joining one hand over the raft and paddling with the other. The capacity of the raft can be increased by stuffing straw or grass between the two ground sheets (or ponchos).

VEHICLE CROSSING DEVICES

7. **Inner Tube Float.** A strong sapling is lashed to the front and rear bumpers of the vehicle and inflated inner tubes are secured to the frame at each corner. This provides adequate flotation for a light vehicle (1/4 ton). Construction time for two soldiers is approximately 30 minutes. Material required is:

a. four strong saplings;

b. six 15 m lashings;

c. eight 5 m lashings; and

d. four MLVW tire inner tubes.

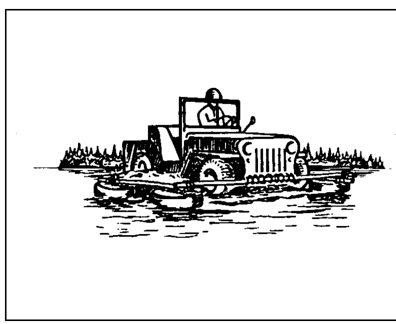


Fig 14-5-4 Inner Tube Float

8. **Canvas Pontoon Float.** Two box frames are constructed of notched saplings lashed together with wire or cordage. The size is 3.5 m x 0.5 m x 1 m. They are then covered with canvas and attached as out riggers to the vehicle by means of cross members lashed to the front and rear bumpers (Fig 14-5-5). Construction

time for two soldiers is approximately 30 minutes. Material required is:

a. Two MLVW tarpaulins;

b. two 5 m lashings; and

c. six 15 m lashings

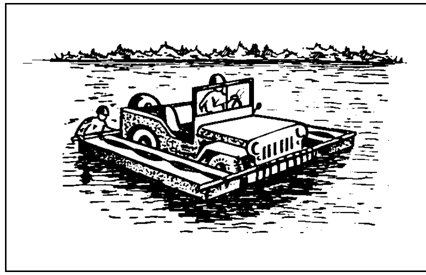


Fig 14-5-5 Canvas Pontoon Raft

9. **Gasoline Drum Raft.** A gasoline drum raft is constructed from twenty 45 gal drums (200 l) and can support a 5/4 ton vehicle plus four to six soldiers with their equipment. The ramps and wheel tracks are constructed of local material or prepared timber. Five outrigger assemblies are constructed with four drums each. Two logs, 5 m long, are placed on the ground 0.40 m apart. Under each end a shorter supporting log is placed to enable the lashing to be passed under the logs. Then four drums are lashed to the two logs to form an outrigger assembly. Three of the outrigger assemblies are placed on the ground close together and the ends of the outrigger logs lashed to the long support log (Fig 14-5-6). The overhang of the support logs must be equal to the support logs leaving a 1.25 m clear space between them and the inside outrigger

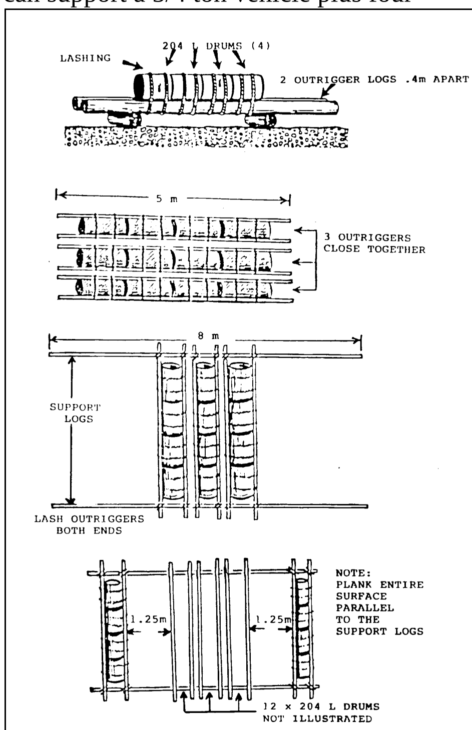


Fig 14-5-6 Gasoline Drum Raft

assemblies. The wheel tracks and ramps are then lashed to the raft and the raft pushed into the water. Construction time for six soldiers is approximately 5 hours. The material required is:

a. twenty 204 litre (45 gal) gasoline drums;

b. ten outrigger logs 5 m x 10 cm;

c. two support logs 8 m x 10 cm;

d. twenty pieces of 6 m lashing;

e. 250 m of 13 mm or 19 mm cordage; and

f. eighteen 3 m x 25 mm x 200 mm planks.

9. **Gasoline Drum Float.** A gasoline drum float consists of a "necklace" of gasoline drums arranged around the vehicle on a rigid frame of timbers to provide flotation for light vehicles up to 5/4 tons. To avoid sudden drops when entering the water and steep banks when leaving the water, the entrances and exits may have to be prepared.

a. Two supporting logs are lashed to the front and rear of the vehicle. These shall be strong enough to take the weight of the vehicle. Two logs 0.75 m long are placed on the ground 0.40 m apart. Under each end a shorter supporting log is placed to enable the lashings to be passed under the logs. Four drums are lashed to the two logs to form an outrigger assembly. Two outrigger assemblies are constructed and lashed one on each side to the supporting log. Enough room shall be left between the outrigger assembly and the tires to allow the wheels to turn. To the front supporting log, two drums are lashed, then another supporting log is lashed across the outrigger logs to prevent the drums from rising out of the water. A single drum is attached to the rear in same manner.

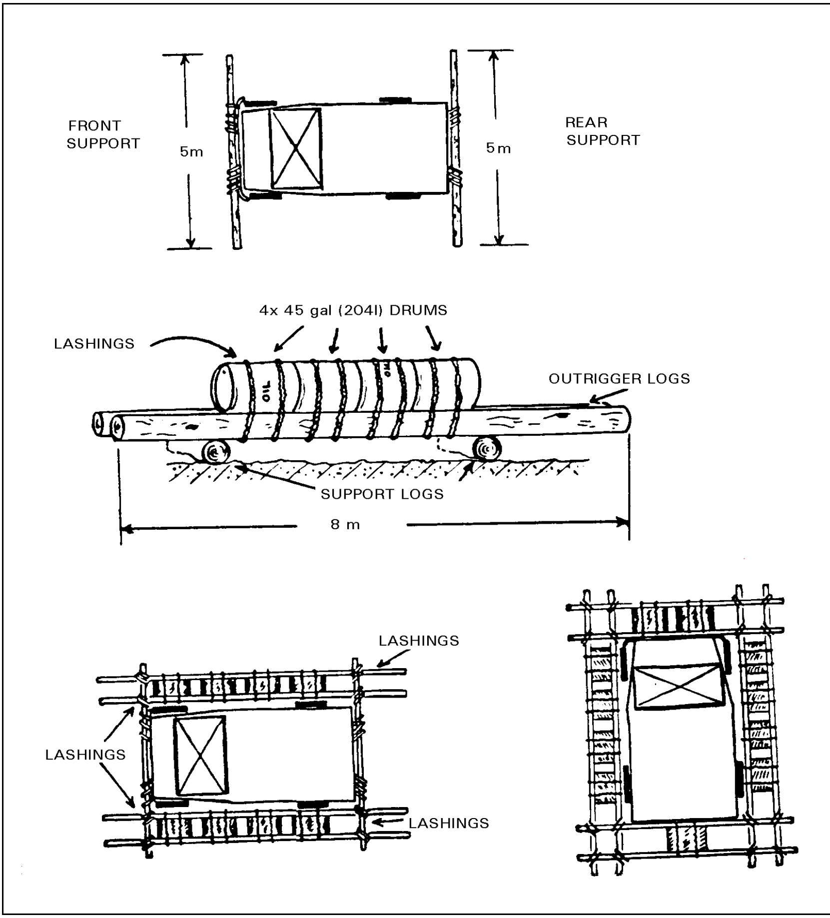


Fig 14-5-7 Gasoline Drum Float

b. Construction time for six soldiers is approximately 4 hours, which does not include cutting and preparation of local material. The material required is:

(1) eleven 200 l (45 gal) gasoline drums,

(2) 100 m of 13 mm or 19 mm cordage,

(3) twenty pieces of 6 mm lashings,

(4) four support logs 5 m x 10 cm, and

(5) four outrigger logs 8 m x 10 cm.

SECTION 6

MILITARY LOAD CLASSIFICATION MARKINGS

1. STANAG 2010 standardizes the method of marking the military load classification of bridges and rafts and the corresponding marking of vehicles. The standard load method on which the computation of the classification of bridges, rafts and vehicles is contained in STANAG 2021. The military method is in no way intended to supersede existing civilian methods. Special arrangements may be made by theatre commanders to indicate vehicles of exceptional width or to indicate exceptionally low overhead obstructions.

MILITARY LOAD CLASSIFICATION SIGNS FOR BRIDGES AND RAFTS

2. **Types of Military Signs**. Bridge and raft signs are of two types:

   a. Circular signs on which is inscribed the bridge or raft classification and which are to be used on all bridges and rafts; and

   b. Rectangular signs which indicate additional restrictions and certain other technical information which are used only when necessary.

3. **Circular Signs.** All bridges and rafts are to have circular signs indicating the military bridge or raft classification. These signs are to have a yellow background with the bridge or raft classification and appropriate symbols inscribed in black. The legend is to be as large as the diameter of the sign allows.

   a. **Normal Circular Signs.**

      (1) **Signs of One-Way Bridges.** These signs are to be a minimum of 40 cm in diameter. (Fig 14-6-1(a)), and

      (2) **Signs for Two-Way Bridges.** These signs are to be a minimum of 50 cm in diameter. They are to show on the left half the two-way classification

and on the right side the one-way classification. (Fig 14-6-1(b)).

b. **Special Circular Signs.**

(1) In those instances where the bridge classification indicates the need for a separate classification of a bridge for wheeled and track vehicles (only if over class 50), a special circular sign, indicating both classes, is to be used for one-way traffic bridges. The wheeled classification is shown above the tracked classification. This sign is to be a minimum of 50 cm in diameter. (Fig 14-6-1(c)).

(2) If similar circumstances pertain in a two-way traffic bridge, normal signs shown in Fig 14-6-1(b) and Fig 14-6-1(d) may be combined at the discretion of the commander concerned.

4. **Rectangular Signs**.

a. Separate rectangular signs are to be used if necessary to denote width or height limitations or other technical information. Width and height signs are not required on bridges where existing civilian signs are already in place and are sufficiently clear. Rectangular signs are to be a minimum of 40 cm in height or width and they are to have a yellow background with the appropriate inscription in black letters, figures or symbols. The inscription is to be as large as the sign allows,

b. The inscription on a sign indicating the bridge or raft width is to consist of two arrows and the bridge or raft width in the metric or Imperial system. These are to be arranged as illustrated in Fig 14-6-1(e).

c. The inscription on a sign indicating the bridge or tunnel height is to consist of two arrows and the bridge or tunnel minimum height in the same manner as indicated in paragraph 5. These are to be arranged in a manner similar to Fig 14-6-1(f).

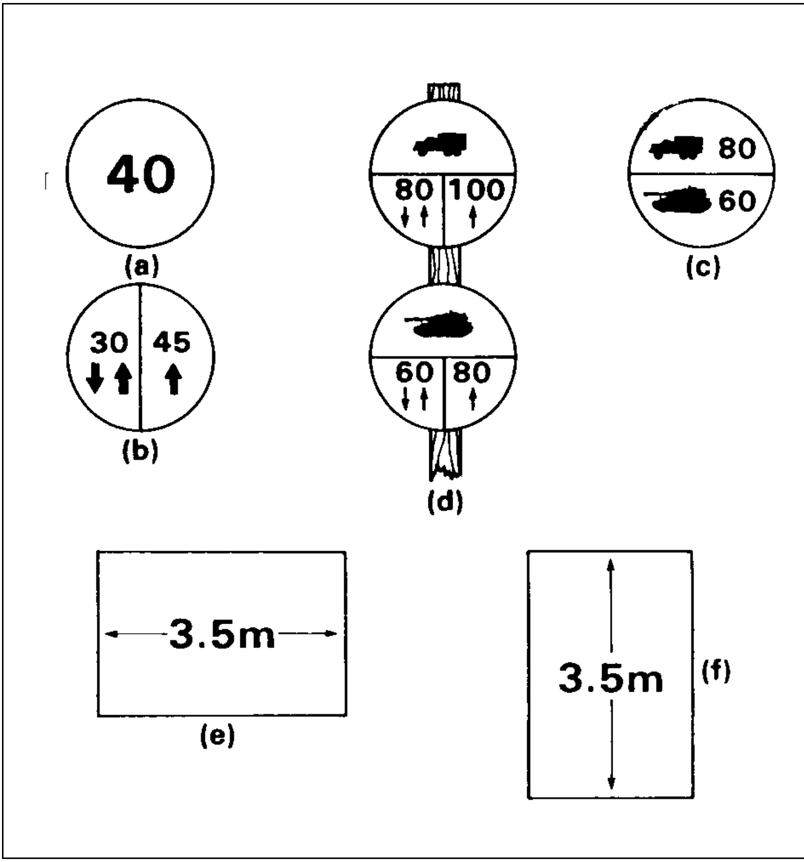


Fig 14-6-1 Standard Bridge and Raft Load Classification Signs

d. If necessary, local commanders may use both metric and Imperial systems or replace one of these two by another system. As regards the signs indicating height and width, the military authorities may, if they deem it convenient, use the Geneva Convention of 1949 signs in the countries party to this Convention.

e. Only those bridges whose width is less than that laid down in STANAG 2021 for the appropriate load classification need carry the sign.

5. **Positioning of Signs**.

a. Bridge or raft classification signs are to be placed at both ends of the bridge or raft in a position to be clearly visible to all oncoming traffic.

b. In addition to the bridge and raft signs outlined above, appropriate warning signs are to be placed at the approaches to the crossing sites when required.

c. Rectangular signs other than those indicating height restrictions are to be placed immediately below the bridge or raft classification sign on the bridge or raft.

d. Signs indicating height restrictions normally are to be placed centrally on the overhead obstruction itself as in civilian practice.

6. **Restricted Lanes.**

a. In the case of damaged bridges where it is necessary to confine traffic to a restricted lane, physical barriers such as posts, barrels, etc, are to be used to define the lane. Wherever necessary, such barricades are to extend throughout the length of the bridge and along the approach roadways in such a manner as to prevent traffic congestion. Adequate warning signs are to be used.

b. In the case of certain bridges, heavier loads can be taken on a restricted lane (such as the centre line of the bridge or the line of the rails on a road and rail bridge) than on other lanes. These restricted lanes are to be marked by painted lines, studs, etc, and rectangular explanatory signs are to be placed at the approaches to the bridge.

MILITARY LOAD CLASSIFICATION SIGNS FOR VEHICLES

7. **Front Signs.** Front signs are used on all vehicles, except trailers, to show the classification of the laden vehicle or train (for details see sub-paragraph 12a).

8. **Side Signs.** Side signs are used on towing vehicles and trailers only, to show the classification of the laden towing vehicles or trailers by themselves.

9. **Shape, Size and Colour of Signs.** Both signs are to be circular in outline and marked in contrasting colours consistent with camouflage requirements. Black figures on a yellow background may also be used. The front sign is to be 23 cm in diameter and the side sign 15 cm in diameter.

10. **Positioning of Signs on Vehicles.**

    a. **Front Sign.** The front sign is placed or painted on the front of the vehicle, above or on the bumper and below the driver's line of vision. Wherever possible, it is to be on the right side, facing forward.

    b. **Side Sign.** The side sign is placed or painted on the right side of the vehicle facing outwards.

11. **Inscription on Signs.** The inscription on the sign is to be as large as the sign allows.

    a. **Front Signs.** The front sign, except on towing vehicles and tank transporters, is to indicate the laden solo class of the vehicle (Fig 14-6-1(a)). On towing vehicles, the front sign is also to indicate the combine load class of the train.

Above this number, the letter “C” is to be written to distinguish the vehicle as a towing machine(Fig 14-6-2). Ontank transporters and similar type vehicles, the fixed front sign is to show the maximum classification of the laden vehicle. In addition, one alternative front sign may be carried which is to be placed so as to cover the fixed front sign when necessary, to show the class of the vehicle when unladen.

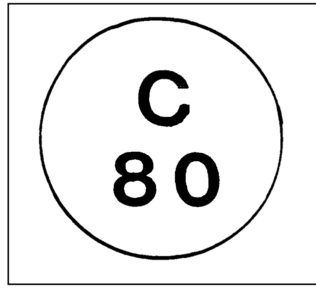


Fig 14-6-2 Front Sign for Towing Vehicle

b. **Side Sign.** The side sign (used only by prime movers of combination vehicles and trailers) includes the laden solo class of the prime mover or trailer.

12. **Signs Carried by Various Vehicles.**

a. **Single Vehicles (including Tank Transporters).** Single vehicles are to carry the front sign only.

b. **Combination Vehicles.** Towing vehicles are to carry both front and side signs.

c. **Trailers.** Trailers are to carry side signs only.

13. **Vehicles to be Marked.** All vehicles in use by NATO Forces are to be marked as described above, however marking of the following is optional:

a. vehicles of a gross weight of 3.048 tonnes or less; and

b. baggage or other pole type trailers with a rated capacity of 1.524 tonnes or less.

CHAPTER 15

HELICOPTER LANDING SITES

SECTION 1

HELICOPTER LANDING CRITERIA

INTRODUCTION

1. The ideal selection criteria and marking systems for helicopter landing sites during day and night operations are prescribed in this chapter. At times, it may be necessary to accept reduced criteria, however the ultimate decision will rest with the helicopter unit. The dimensions may require alteration as new types of helicopters are introduced.

2. The preparation and maintenance helicopter landing facilities varies according to the tactical situation, location, site conditions and expected duration of use. Given the short duration of use in the area of operations, tactical helicopter landing sites are not designed in great detail. Those likely to be in semi-permanent use (ie, for a field hospital) require more detailed design. Horizontal construction procedures described in B-CE-320-012/FP-002 and B-CE-320-012/FP-003 are used.

3. Engineers are generally responsible for the reconnaissance and construction of the more permanent helicopter landing facilities, both in the combat zone and in the rear area. The marking of tactical helicopter landing sites for a particular operation which does not require any construction work may be done by all arms units. Land force engineers are responsible for the construction and maintenance of temporary helicopter landing sites in the land force area of operation. Airfield engineers are responsible for the design, construction and maintenance of heliports in the area of operations. Heliports are beyond the scope of this manual.

TERMINOLOGY

4. **Helicopter Landing Zone**. A specified zone used for landing helicopters.

5. **Helicopter Landing Site**. A site within a landing zone containing one or more helicopter landing points.

6. **Helicopter Landing Point**. A point within a landing site where one helicopter can land.

7. **Heliport**. Permanent facilities used for the landing and servicing of helicopters.

8. **Helipad**. A point within a heliport where one helicopter can land.

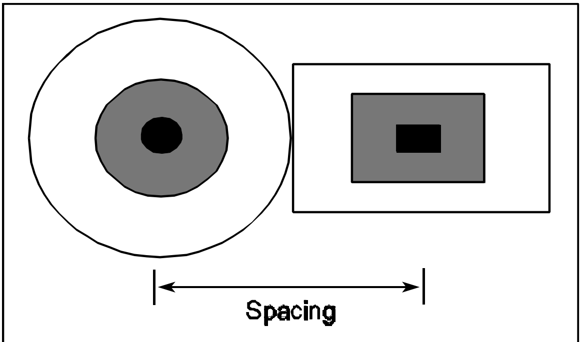
9. **Cleared to Ground Level**. To ensure a safe landing, it is essential that solid obstacles, and inflammable and loose material be cleared. The term "cleared to ground level" is used to indicate this. It is not necessary to clear grass up to 0.3 m (1 ft) high that covers a level field unless a fire risk exists.

10. **Hard Surface**. The hard surface centre of the landing point, where the helicopter lands, must be solid enough to bear its weight.

11. **Note**. An exception can be made if ground obstructions cannot be cleared. Some helicopter operations can be conducted with the helicopter hovering and not actually landing. The same dimensions for cleared areas and ground markings are required. Every effort shall be made to clear the landing point surface to permit the aircraft to land.

HELICOPTER LANDING POINT CRITERIA

12. **Dimensions**. The size of the landing site will depend on the number and size of landing points within it, and the dispersion required between the landing points based on the tactical situation. The criteria provided in Fig 15-1-1 represents the minimum dimensions for the size of each landing point. Helicopter units will designate the size and shape of the landing points to be utilized for specific operations. Numerous considerations, such as type of helicopter, unit proficiency, load, climatic conditions, and day or night operations may affect the size of landing point required. In the absence of information from the helicopter unit, a size 3 landing point will be provided. Types of NATO helicopters and their required landing point sizes are given at Annex A.



Size	Spacing (m)
1 (Recce, Utility & Attack)	25 m
3 (CH47 & Cargo)	50 m
5 (Support)	100 m

Size	Circular (diameter)			Rectangular		
	Hard surface	Cleared to ground level	No obstacle over 0.6 m high	Hard surface	Cleared to ground level	No obstacle over 0.6 m high
1 (Recce, Utility & Attack)	6 m	14 m	25 m			
2 (CH47 & Cargo)	15 m	35 m	50 m	15x10 m	35x20 m	50x35 m
3 (Support)	15 m	60 m	100 m	15x10 m	60x20 m	100x50 m

Fig 15-1-1 Dimensions of Helicopter Landing Points

13. **Separation Distance**. The minimum recommended distance, centre to centre, between landing points within a landing site where no dispersion is required between helicopters is given in Fig 15-1-1.

14. **Approaches**. Ideally, there will be approach and exit paths into the wind which are free of obstructions. The criteria below represents the minimum required to permit full flexibility in helicopter operations. Approaches which do not meet these criteria may be acceptable depending on the nature of the operations undertaken. For example, in light wind conditions, a single approach and reciprocal exit may be acceptable.

However, when these criteria cannot be met, the helicopter unit is to be consulted.

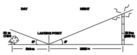
a. **By Day**. Within the selected approach and exit paths, the normal maximum obstruction angle to an obstacle should not exceed 6° out to a distance of 500 m from the cleared to ground area (Fig 15-1-2). This allows a maximum obstacle height of 52 m at 500 m.

b. **By Night**. The selected approach and exit paths should contain a sector of not less than 16° in azimuth as measured from the landing point. The width of the approach and exit paths should not be less than the width of the area of the landing site cleared to 0.6 m. Less than 50 m will not be acceptable, and more than 100 m is not necessary. Within the selected approach/exit paths, the maximum obstruction angle shall not exceed 4° as measured from the landing point cleared to ground area to a distance of 3000 m (Fig 15-1-2). This permits a maximum obstacle height of 210 m at 3000 m.

(1) When the emergency or primary method of marking the landing site is used, the maximum obstruction angle on the approach and exit paths is reduced to 4° (or 1 in 16).

(2) When a glide path indicator is used, the obstruction angle is increased to 6° and shall be extended to the range of the indicator, or 3000 m whichever is greater, and cover the projection angle of the indicator in azimuth.

(3) There are no restrictions on the obstruction angle to obstacles other than those within the approach and exit paths. However, prominent obstructions in the area of the landing site which are not marked on the map are to be reported to the helicopter unit.



NOTES: 1. By day, the obstruction height cannot exceed an approach angle of 6° to 500 m from the landing point.2. By night, the obstruction height cannot exceed an approach angle of 4° to 3000 m from the landing point.

Fig 15-1-2 Landing Point Obstruction Angle on Approach and Exit Paths - Day and Night.

15. **Surfaces.** The surface of the centre of the landing point must be flat and sufficiently firm to allow a fully loaded ground vehicle (eg, Iltis for light helicopters; MLVW for larger helicopters) to stop and start without sinking. The whole landing point is to be cleared of any loose material or piles of dust and sand that could be blown up by the rotors of the helicopter. Landing points with sandy or dusty surfaces shall be stabilized or covered with a membrane or trackway. Snow on a landing point shall be packed or removed to reveal any hazardous objects and reduce blowing snow. A marker is essential to provide a visual reference for depth perception and also to reduce the effect of white-out.

16. **Ground Slope**. Ideally, the ground on the landing site should be level. Where a slope is present, it shall be uniform. If the following criteria cannot be met, the use of the landing site must be confirmed by the helicopter unit:

a. **By Day**. Slope should not exceed 7° (or 1 in 8) if the helicopter is to land. However a greater slope may be acceptable for hovering helicopters; and

b. **By Night**. A reverse slope, as viewed from the approach path, is not normally acceptable. A forward and lateral slope should normally not exceed 3°(or 1 in 19).

TACTICAL CONSIDERATIONS

17. **Concealment**. A landing site in close proximity to the Forward Line of Own Troops (FLOT) shall be masked from ground and electronic observation. The selection of approach and exit routes shall also be based on the availability of good masking features.

18. **Protection**. Field fortifications may have to be constructed by engineers at permanent heliports.

19. **Designation of Landing Zones and Sites**. Landing zones are designated by a colour or codeword. Landing sites are designated by landing zone colour or codeword/prefix and number. Where unit landing zones are larger, the numbering of landing sites can be grouped by geographical or sub-unit areas. Thus the landing sites in one sub-unit area may be known as RED 30, RED 31, etc, and in another sub-unit area the landing sites may be designated RED 40, RED 41, etc.

20. Communications Equipment. Whenever radio communication and electronic aids, (including air traffic control facilities) are located at a landing site, antennae shall be offset from the landing site to prevent the opposing force from fixing the location of the site with electronic devices. Only essential communications equipment for controlling the helicopters at the landing site shall be used.

SECTION 2

MARKING HELICOPTER LANDING SITES

GENERAL

1. Landing sites and points shall be marked when circumstances allow. Marking shall be kept to the minimum and only displayed when actually required so as not to disclose the position. Some methods of marking the landing site by day and night are described and illustrated here, but other methods may be used by other nations. A thorough briefing is necessary before a night operation.

2. **Display of Markers.** There is a danger of unsecured markers being dislodged by the downwash from the helicopters, and causing damage by being drawn into the rotor or engine. Panels or lights shall therefore be firmly secured, or removed before the helicopter hovers above them.

VISUAL IDENTIFICATION

3. The visual identification of a landing site may be made by a variety of methods:

a. pre-arranged display of figures, letters, light codes or a marshaller.

b. carbide-inflated, yellow marker balloons. The balloons must be lowered once the helicopters have acknowledged recognition.

c. coloured smoke, flashing lights, or pyrotechnics. To prevent deception by the hostile forces, the following identification sequences shall be used:

(1) the ground unit initiates the visual identification method, ie releases smoke etc, on request;

(2) the helicopter pilot states the colour he sees;

(3) the ground unit confirms colour is correct, and then

(4) the helicopter lands.

4. **Coloured Lights**. Red lights are reserved for the indication of obstacles.

DAY MARKING

5. The letter "H" indicates a helicopter landing site. Individual landing points within a landing site may be indicated by a ground marshaller, or panels or any type of obvious marker such as a small flag. Indication of wind direction is desirable and may be provided by the marshaller with his hands raised and his back to the wind. Smoke may also be used but should be placed at the downwind side to avoid obscuring the touchdown point. Where it is necessary to differentiate between neighbouring landing zones, sites, or points, details will be given in the plan.

NIGHT MARKING

6. At night, approaches to a tactical landing site requires the use of a tactical landing light system which shall be capable of providing the aircrew with visual cues that will aid in determining alignment with the approach axis, angle of descent, rate of closure and provide a ground hover reference. The source of light may consist of hand-held flashlights, beanbag lights, phosphorescent tubes, etc. Regardless of the type of light source used, it shall be capable of being secured so that the wind force of the helicopter will not cause it to move, or extinguish it. If a battery-powered light is used, it is desirable that each light yield approximately the same light intensity. White light provides the best light source for a tactical landing light system.

7. Prior to the arrival at a landing site, it is essential that the aircrew know which system is being employed. The aircrew shall receive this information from the supported unit in the operation briefing or by radio from the ground party establishing the landing point.

8. The two recommended tactical landing light systems are the "T" and the inverted "Y" (Fig 15-2-1). Both systems provide the visual cues required by the helicopter crew to execute a safe approach to a tactical landing site. The national preferences for "T" or "Y" use are shown in Fig 15-2-2. Additional reference lights may be requested by the helicopter unit

when there is more than one landing point in the same vicinity or if the helicopter is engaged in picking up or unloading slung loads at night.

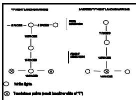


Fig 5-2-1 “T” and “Y” Lighting Systems

9. Other systems requiring fewer lights may be used as an emergency system however, no less than two shall ever be used. Viewing one light causes an apparent motion of the light and results in a false interpretation by the aircrew. The separation between the lights is very important. If only two lights are used, a minimum separation of 5 m (paces) is required.

Ser	Countries	Preference	Notes
	a	b	c
1	BE, LU, NL, TU	None	
2	CA, DA, FR, GE, GR, IT, NO, PO, UK	"T"	CA prefers the "T" but will accept the "Y"
3	US	"Y"	Inverted

Fig 15-2-2 National Preferences for Night Approach Lighting Systems

10. The glideslope indicator used in land operations casts three separate coloured beams of light: amber (top beam), green (centre beam), and red (bottom beam). Any variation of the colour coding must be clearly briefed to the aircrew.

11. Landing Light System for Night Vision Devices. The light intensity of most night lighting devices is too bright for night vision aids with light amplification. A method of reducing the light intensity is required when the aircrew is equipped with a night vision system (goggles). Both the "T" and the "inverted Y" tactical landing light systems with modified lights provide the required visual cues for an aircrew using night vision devices. The use of a landing light system will not always be required. When a high level of ambient light prevails, it may be advantageous to perform the approach without any ground lights. During conditions of low ambient light, the tactical landing light system is used in the same manner as when conducting an approach with unaided vision.

12. "T". Spacing between lights of the "T" should be approximately 10 m (10 paces), however nations, including Canada, vary this slightly. National preferences for dimensions in the “T” system are outlined in Fig 15-2-3. The helicopter normally lands to the left or right of the end light in the stem of the “T”. If a glide slope indicator is used with the "T", it shall be positioned beyond the bar of the “T” and aligned with the stem.

13. "Inverted Y". The recommended spacing between lights is shown in Fig 15-2-2. Approaches to the "inverted Y" should terminate with the nose of the helicopter centred on line with the first two lights. If a glide slope indicator is used with the "inverted Y" it is to be positioned beyond the second light in the stem and aligned with it.

Ser	Countries	Distance		Notes
		"A"	"B"	
	a	b	c	d
1	BE, LU, TU	-	-	
2	CA	5 m (16 ft)	15 m (49 ft)	
3	DA, GR, IT, NL, PO, UK	10 m (33 ft)	10 m (33 ft)	
4	NO, US	5 m (16 ft)	8 m (26 ft)	
5	FR, GE	10 m (33 ft)	10 m (33 ft)	There may be four lights in the "stem" of the "T"

Fig 15-2-3 National Preference of Distances for the "T" Lighting System

14. **Emergency Method.** Two light vehicles (1/4 ton or low silhouette) are placed 35 m apart and 35 m downwind of the centre of the landing point with their headlight beams intersecting at the centre of the landing point (Fig 15-2-4).

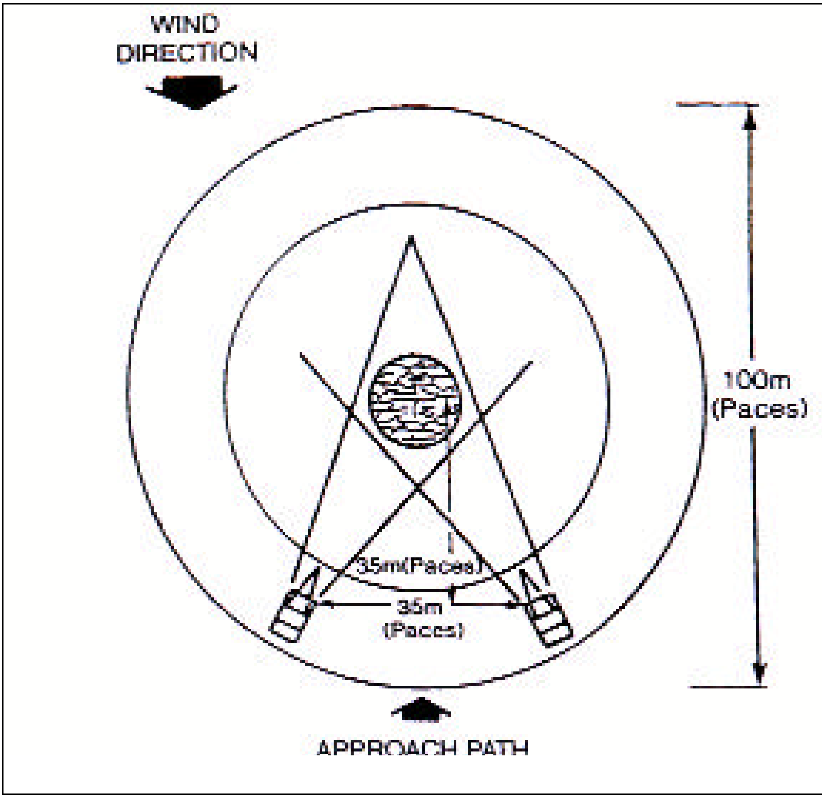


Fig 15-2-4 Emergency Method of Marking a Landing Point

ANNEX A

HELICOPTER LANDING SITE REQUIREMENTS

Nation	Helicopter Type	Role	Size
(a)	(b)	(c)	(d)
Canada	CH-147 GRIFFON	Utility	1
Denmark	OH-6 CAYUSE AS 550 FENNEC	Recce/Obsn Antitank	1 2
France	AP II 3130 AP III 3160 SA 341C SA 342C SUPER FRELON	Liaison Combat Combat Combat Transport	2 2 2 2 2
Germany	CH-53 G UH-1D ALOUETTE II BO 105 M/P	Support Support Liaison Recce/Liaison & Antitank	3 2 2 2
United Kingdom	CHINOOK HC Mk 1 PUMA HC Mk 1 SEA KING Mk 4 WESSEX HC Mk 2 LYNX AH Mk 1, Mk 7 GAZELLE AH 1 SCOUT AH 1	Support Support Support Support Utility/Antitank LOH/Liaison Utility	2 2 3 2 1 1
United States	OH-6 CAYUSE OH-58(C,D) KIOWA UH-1(H) IROQUOIS UH-60 BLACKHAWK CH-47(C,D) CHINOOK CH-54(B) TARHE AH-1(S) COBRA AH-64 APACHE AH-1T SEA COBRA AH-1W SUPER SEA COBRA UH-1N HUEY CH-46E SEA KNIGHT CH-53A (A, D) SEA STALLION CH-53E SUPER SEA STALLION	Recce/Obsn Recce/Obsn Utility/Transport Utility/Transport Cargo/Transport Cargo/Transport Attack/Antitank Attack Attack Attack Utility Assault/Support Assault/Support Assault/Support	1 1 2 2 2 2 2 2 2 2 1 2 3 3