# ENGINEERS' REFERENCE 

## AND LOGISTICAL DATA




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Table 176, National Design Specification for Stress-Grade Lumber and its Fastenings, revised 1955, from National Lumber Manufacturers Association.

Table 172, Tentative Specifications for Billet-Steel Bars for Concrete Reinforcement, A.S.T.M. Designation A15-58T, revised February 1959, from American Socicty for Testing Materials.

Table 175, Manual of Structural Design, Third Edition, pages 8 through 33, from H. M. Ives and Sons, by J. Singleton.

Tables 146, 150 through 154, from Steel Construction, Fifth Edition, from American Institute of Steel Construction, copyrighted 1947.

Table 97, Guicle to Horsepower Limits of Individual Motors for Different Systems, page 999, American Electricians' Handbook, 1953 edition, from McGraw-Hill Book Company, Inc.

Portions of paragraph 165 and 169, Tables 171 and 187, from American Concrete Institute, May 1956, paragraph 506 and 1303. Building Code Requirements for Reinforced Concrete, 5th printing pages 22 and 23 ; formula 30 on page 96 ; Table 9 on page 52 ; diagram 17 on page 58 and Table 15 on page 57 of the Reinforced Concrete Design Handbook, 2d edition, from American Concrete Institute.

Figure 46, from Section 20, page 311, Nomogram for Calculating Pipe Size, discharge and head loss, American Pipe Manual, from American Cast Iron Pipe Company.

Figure 58, from Audels New Electric Library, by Frank D. Graham, Theo Audel and Co., Publishers.

Figures 72 and 74, from Architects and Builders Handbook, by Kidder and Parker.

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Figure 6, from Data Book for Civil Engineers-Design 1945 edition, by Elwyn E. Seelye.

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## CHAPTER 1 <br> INTRODUCTION

## 1. Purpose

This manual is intended to provide engincer and other military personnel at all lcvels, including operations and planning officers, with a compilation of data for usc as a guide in the logistical planning of enginecr activitics.

## 2. Scope

a. The manual includes logistical data pertaining to cnginecr troops, cquipment, matcrials, and installations, and to all types of enginecractivitics, including fortifications, camouflage, roads, railroads, bridges, airficlds, utilities, and gencral construction. It also contains misccllancous physical and mathematical data and conversion tables.
$b$. The material presented hercin is applicable without modification to both nuclear and non-nuclear warfare.

## 3. Relation to Other Manuals

Various manuals of the FM 5-, TM 5-, and AFM 88-series contain detailed logistical data on the above topics, and on individual itcms of engineer cquipment in temperate climates. This manual is confined to summarizing such information and stating what sources should be consulted for further details.

## CHAPTER 2 <br> ENGINEER TROOPS

## 4. General

FM 5-5 sets forth the mission, assignments, capabilities, organization, and normal employment of all engineer troop units. The TOE's for these units give further personnel and equipment details.

## 5. Strength of Engineer Units

The tabulation in table 1 gives basic data on engineer troop units; that in table 2 , on engineer teams listed in TOE $5-500 \mathrm{C}$. The data is subject to change and the latest appropriate TOE list should also be consulted.

Table 1. Engineer Troop Units

| TOE No. | Unit | Authorized strength |  |  |  | Normal assignment | Mission, capabilities, and remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |  |
|  | ENGINEER COMMAND UNITS |  |  |  |  |  |  |
| 5-301 | Headquarters and headquarters company, engineer brigade. | 29 | 6 | 107 | 142 | Communications zonc, task force, army, or high headquarters. | Commands engineer units totaling 9,000 to 15,000 men. |
|  | Engineer combat units |  |  |  |  |  |  |
| 5-15 | Infantry division engineer battalion. | 42 | 4 | 739 | 785 | Infantry division------ | Provides general engineer support for infantry division. Combat companies can operate independently. |
| 5-16 | Headquarters and hcadquarters company, infantry division engincer battalion. | 22 | 4 | 224 | 250 | 1 per battalion.......-- | Provides division engineer special staff and command staff, communication, reconnaissance, supply, maintenance, and supplemental heavy equipment for the infantry division engineer battalion. |
| 5-17 | Engineer company, infantry division, engineer battalion. | 4 | 0 | 103 | 107 | 5 per battalion-------- | Provides general engineer support for infantry division. Combat companies can operate independently. |
| 5-35 | Engineer combat battalion, army. | 30 | 3 | 586 | 619 | 3 per cngineer combat group. | As component of engineer combat group, provides general engineer support for a corps or army. Combat battalions can operate independently. |

Table 1. Engineer Troop Units-Continued

| TOE No. | Unit | Authorized strength |  |  |  | Normal assignment | Mission, capabilities, and remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |  |
| 5-36 | Headquarters and headquarters and service company, engineer combat battalion, army. | 15 | 3 | 139 | 157 | 1 per battalion ${ }_{\text {- ------- }}$ | Provides command and staff, communications, reconnaissance, supply, maintenance, and supplemental equipment for the engincer combat battalion, army. |
| 5-37 | Engineer combat company, army. | 5 | 0 | 149 | 154 | 3 per battalion-------- | Provides an opcrating component of the cnginecr combat battalion for performance of gencral engincer work contributing to combat effcctiveness of corps and army. |
| 5-67 | Engineer water supply company. | 5 | 0 | 105 | 110 | 1 per field army or 1 per 400,000 troops in communications zone. | Can produce 27,000 gallons per day of potable watcr; transport 18,000 gallons in one lift. |
| 5-96 | Headquarters and headquarters detachment, engineer camouflage battalion. | 6 | 3 | 54 | 63 | Army communications zonc. | Provides camouflage support for ficld army, or equivalent dcmand in communications zone. |
| 5-97 | Engineer camouflage company. | 5 | 0 | 65 | 70 | 3 per battalion or field army. | Provides camouflage support for ficld army, or equivalent demand in communications zone. |
| 5-137 | Engineer panel bridge company. | 4 | 0 | 124 | 128 | Corps, army $\ldots$.-. .-.-. | Has one 130-foot, 40-ton panel bridge. |
| 5-138 | Enginecr float bridge company. | 8 | 1 | 209 | 218 | 2 pcr corps, 9 additional for ficld army. | Has 700 feet of M4T6 bridge or 10-four-float M4T6 rafts or combinations of bridges and rafts. |


| 5-192 | Engineer combat group. | 16 | 1. | 64 | 81. | 2 per corps; 3 per ficld army. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 5-5 | Armored division engineer battalion. | 41 | 4 | 870 | 915 | Armored division------ |
| 5-6 | Headquarters and headquarters company, arınored division engineer battalion. | 19 | 4 | 188 | 211 | 1 per battalion.-.-...- |
| 5-7 | Engineer company, armored division engineer battalion. | 5 | 0 | 161 | 166 | 4 per battalion------- |
| 5-8 | Bridge company, armored division engineer battalion. | 6 | 0 | 144 | 150 | 1 per battalion------. |
| 5-225 | Airborne engineer battalion. | 33 | 4 | 627 | 664 | Airborne division |
| 5-226 | Headquarters and headquarters and service company, airborne engineer battalion. | 16 | 4 | 163 | 183 | 1 per battalion_....... |
| 5-227 | Airborne engineer company. | 5 | 0 | 149 | 154 | 3 per battalion------- |
| 5-367 | Engineer light equipment company. | 5 | 1 | 180 | 186 | 1 per engincer combat group. |
| 5-412 | Headquarters and headquarters company, engineer aviation group. | 15 | 5 | 91. | 111 | Engincer aviation brigadc, major air force. |

Provides general engineer support for a corps or field army.
Provides general engineer support for armored division. Armored companies can operate independently. Bridge company has 576 feet of floating bridge.
Provides the division engineer special staff section; and command and staff, communication, reconnaissance, supply, and maintenance for the armored division engineer battalion.
Provides general engineer support for armored division. Armored companies can operate independently.
Provides general engincer support for armored division. Bridge company has 576 feet of floating bridge.
Provides general engineer support for airbornc division.
Provides general engineer support for airborne division.

Provides general engineer support for airborne division.
Auginents group for construction support of a corps or field army.
Controls 2 to 4 aviation battalions and attached troops.

Table 1. Engineer Troop Units-Continued

| TOE No. | Unit | Authorized strength |  |  |  | Normal assignment | Mission, capabilities, and remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |  |
| 5-420 | Engincer Amphibious Support Command. <br> ENGINEER CONSTRUCTION UNITS: | 243 | 43 | 3, 491 | 3, 768 | 1 per theater... | Provides amphibious planning, assault lift, shore repair control for a corps in amphibious assault. |
| 5-312 | Headquarters and headquarters eompany, engineer construction group. | 14 | 3 | 62 | 79 | Army, communications zone. | Commands 1 to 4 enginecr construetion battalions and up to 2,000 other engincer troops. |
| 5-324 | Enginecr dump truck company. | 4 | 1 | 103 | 108 | Engincer group or brigadc. | Operates 48 dump trucks, 5 -ton; must be loaded by supported unit; drivers for 2 shifts. |
| 5-328 | Engineer heavy equipment company. | 4 | 2 | 162 | 168 | IEngineer group. | Operates and maintains heavy equipment to augment construction units. |
| 5-329 | Enginecr port construetion company. | 7 | 4 | 220 | 231 | Army, communications zone. | May be attached to engincer construction group to augment it for port construetion; has diving and special equipment including floating cquipment. |
| 5-115 | Engineer heavy construetion battalion. | 28 | 11 | 751 | 790 | Theater air foree, army, eommunications zone. | All types of heavy construction, with speeial reference to airficld construction and allied activitics. |

5-116 $\left.\left.\left\lvert\, \begin{array}{c}\text { Headquarters company, } \\ \text { engineer construction } \\ \text { battalion. } \\ \text { Engineer service and } \\ \text { support company, } \\ \text { engineer construc- } \\ \text { tion battalion. } \\ \text { Engineer construction } \\ \text { company. }\end{array}\right.\right\} \begin{array}{l}5-117 \\ 5-376 \\ \begin{array}{l}\text { Headquarters and head- } \\ \text { quarters detachment, } \\ \text { engineer pipeline } \\ \text { group. } \\ \text { Headquarters, head- } \\ \text { quarters and service } \\ \text { company, engineer } \\ \text { pipeline battalion. } \\ \text { Engineer pipeline } \\ \text { company. }\end{array} \\ 5-48 \\ \text { Engineer supply point } \\ \text { company. } \\ \text { AND supply units }\end{array}\right\}$
13

All types of heavy construction, with special reference to airfield construction and allied activities.
All types of heavy construction, with special reference to airfield contruction and allied activities.

All types of heavy construction, with special reference to airfield construction and allied activities.
Prepares plans for bulk petroleum handling systems and commands and supervises pipcline construction and maintenance units.
Commands, plans, and supervises the construction, rehabilitation, and field maintenance of petroleum distribution and storage facilities. Constructs and rehabilitates petroleum unloading and bulk storage facilitics and pipeline systems; partial field maintenance of petroleum pipeline systems.

Operates engineer supply point in the corps and army areas. May be used to distribute supplies to a large concentration of construction projects or to operate issue section of a large depot.

| TOE No. | Unit | Authorized strength |  |  |  | Normal assigument | Mission, eapabilitics, and remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |  |
| 5-157 | Engineer field maintenance company. | 5 | 5 | 188 | 198 | Field army or communications zone. Organie to amphibious support brigade. | Provicles engineer field maintenance and parts to supported units for organizational maintenanee. |
| 5-262 | Headquarters and headquarters eompany, engineer maintenance and supply group. | 15 | 8 | 108 | 131 | Army eommunieations zone. | Commands group, normally 2 or more battalions of service troops. |
| 5-266 | Headquarters and headquarters detaehment, engineer depot battalion. | 5 | 3 | 38 | 46 | Communications zone_- | Commands 2 to 5 depot and other supply companies. |
| 5-267 | Engineer depot company. | 4 | 2 | 195 | 201 | Communications zone.- | Operates general engineer supply depot for engineer troops, with labor units attaehed. |
| 5-278 | Engineer depot maintenance eompany. | 4 | 4 | 191 | 199 | Maintenance and supply groups in eommunieations zone. | Normally assigned with a parts depot company to support 3 to 4 field maintenance companies. |
| 5-279 | Engineer parts depot, company. | 4 | 2 | 172 | 178 | Engineer maintenance and supply group. | Provides parts support for 9,000 items of engineer equipment. |
| 5-387 | Engineer forestry company. | 4 | 0 | 142 | 146 | Communications zone_ | Logs timber and operates sawmill; 20 to 40 M. b.m. per day. |

5-464 \(\left.\left\lvert\, \begin{array}{c}Engineer company, <br>
Redstone. <br>
ENGINEER TOPOGRAPHIC <br>
AND INTELLIGENCE <br>
UNITS <br>
Enginecr topographic <br>

battalion, army.\end{array}\right.\right\}\)| Headquarters and hcad- |
| :---: |
| quartcrs company, en- |
| gineer topographic bat- |
| talion, army. |$|$

Table 1. Engineor Troop Units-Continued
TOE No.

| 5-347 | Engincer base reproduction company. | 2 | 3 | 118 | 123 | 1 each por headquartcrs and headquarters company, engineer base topographic battalion. | Reproduces maps, charts, and allicd mapping matcrials such as map indexcs, trig lists, and gazctteers as required. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 5-348 | Engineer base survey company. | 6 | 4 | 155 | 165 | 1 or morc per headquarters and headquarters company, engineer base topographic battalion as required, or may operate independently. | Pcrforms field surveys and computations relative to new mapping or map revision; performs second and third order geodetic surveys; augments field armies' survey capabilities. Performs surveys for military mapping, artillery, and guided missile needs. |
| 5-349 | Engineer base photomapping company. | 4 | 3 | 177 | 184 | 1 each per headquarters and headquarters company, enginecr base topographic battalion. | Provides new and revised map manuscripts for reproduction of multicolored maps; compiles new maps from aerial photography. Prcpares controlled mosaics. |

Table 2. Engineer Teams

| Designation | Name | Authorized strength |  |  |  | Capabilitics and basis of allocation |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |
|  | administrative and headquarters teams |  |  |  |  |  |
| AA. | Platoon headquarters, component of company. | 1 | 0 | 1 | 2 | Capabilities: Command and administrative control of 2 or more service teams. <br> Basis of Allocation: Onc per two or more service teams with a strength of not less than 40 individuals. Not required if commissioned officers are assigned to the teams. |
| AB | Platoon headquarters, separate. | 1 | 0 | 3 | 4 | Capabilitics: Command and administrative control of two or more teams not a part of a company. <br> Basis of Allocation: One per unit comprising 40 to 60 individuals. Not required if commissioned officers are assigned to tcams. |
| AC. | Company headquarters -- | 2 | 0 | 6 | 8 | Capabilitics: Command and administrative control of two or more service teams. <br> Basis of Allocation: One per unit comprising 2 or more service platoons with an aggregate strength of not less than 120 individuals. |
| AD. | Battalion headquarters.-. | 5 | 2 | 15 | 22 | Capabilities: Command and administrative control of 3 or more scrvice companies, or a group of engineer units of company smaller size with an aggregate strength of approximately 750 to 1,100 individuals; furnishes direct administrative assistance to separate detachments which are not attached to companies. <br> Basis of Allocation: One per group of 3 or more service companics, or teams with an aggregate strength of 750 to 1,100 individuals. |
| BA------- | General supply ---------- | 0 | 1 | 23 | 24 | Capabilitics: Receives, stores, issucs, and uaintains records of class II and IV supplies for approximately 35,000 troops. |



Basis of Allocation: Normally augments Enginecr Depot Company, TOE 5-267, and may augment TOE 5-500, Depot Operating Team BB ; one per special task force up to 35,000 troops.
Capabilitics: Operates a depot for the reccipt, storagc, and issuc of enginecr gencral supplies and equipment, and maintains records of class II and IV supplics for approximatcly 90,000 troops.
Basis of Allocation: Normally augments Enginecr Depot Company, TOE 5-267, onc per special task forec from 70,000 to 90,000 troops.
Capabilitics: Operates a small depot for the receipt, assembly, servicing, issuc, and shipment of engincer mechanical and elcetrical equipment in support of a small task force or basc. Capable of cquipment supply for a force which includes approximately 35,000 troops; assembly and initial conditioning of heavy cngincer cquipment for storage or issue to using units; inspection and minor repairs on heavy equipment to dcpot stock to insure serviceability and maintenance of cquipment while in storage.
Basis of Allocation: Augments Engincer Dcpot Company, TOE 5-267, and Engincer Depot Battalion, TOE 5-266, and may augment TOE 5-500, Dcpot Opcrating Team BB; one per special task force up to 35,000 troops.
Capabilitics: Provides the administrative personnel to staff a Theater Engincer Supply Control Office. When augmented by Tcams BE, BF, BG, and BH, the unit comprises a Theater Engineer Supply Control Office capable of: Forecasting gencral cngincer and repair parts supply requirements of a Theater of Operations to insure maintenance of adcquate and realistic stock lcvels; cvaluating stock status reports, tonnage reports, and other spccial supply reports as required or dirceted; directing the distribution or relocation of supplies; asscmbling statistical data pertaining to engineer cquipment population and distribution; gencral engineer and repair parts usage experience, identifying and cataloging locally procured items and other pertinent stock control operations.
Basis of Allocation: One per Theater Headquarters.

| Designation | Name | Authorized strength |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |
| BE. | General engineer supply control team. | 1 | 1 | 41 | 43 |
| BF- | Engineer repair parts | 1 | 1 | 41 | 43 |
| BG | Distribution (stoek eontrol) team. | 1 | 1 | 34 | 36 |

Capabilities and basis of allocation

Capabilities: Provides the neeessary supervisors, analysts, and typists to exercise effeetive supply control over approximately 10,000 to 11,000 general engineer supply items. Maintains a balaneed supply of general engineer items throughout the entire Theater of Operations. Foreeasts requirements and resupply of general engineer items for future operations to insure the receipt and ultimate distribution of neeessary supplies at the proper time and place.
Basis of Alloeation: One for eontrol of approximately 10,000 to 11,000 general engineer items.
Capabilities: Provides the necessary supervisors, analysts, and typists to exereise effeetive supply eontrol over approximately 8,000 to 10,000 rapid turnover repair parts supply line items. Maintains a balaneed supply of repair parts items throughout the entire Theater of Operations. Foreeasts requirements and resupply of repair parts items for future operations to insure the reeeipt and ultimate distribution of neeessary supplies at the proper time and place.
Basis of Alloeation: One for control of approximately 8,000 to 10,000 rapid turnover repair parts supply line items.
Capabilities: Provides the necessary qualified persomnel to exercise effeetive stoek control over all general engineer and repair parts items present in or requisitioned for a Theater of Operations. Works in elose coordination with the other teans of the Engineer Supply Control Offiee. Requisitions items from the zone of interior, direets shipments to various storage depots, diverts shipments as neeessary, authorizes depot issues, controls ship-

ments in and out of depots in accordance with regulations, controls the disposal of excess and unservieeable items. Bascd on data furnished by the Theater Army Engineer, with regard to future operations, prescribes depot missions so as to insure effective and proper distribution of available supplies.
Basis of Allocation: One or more as required per Theater Engineer Supply Control Offiec
18 Capabilities: Identifies and eatalogs repair parts and general engineer items of supply which have been locally proeured or whieh through occurrence or omission have lost their identity. Maintains eonstant liaison with the Theater Procurement Office and local manufacturers to cletermine facilities and materials available. Prepares the necessary clrawings and blueprints required when requesting bids from local manufacturers. Subscquent to inspection and acceptance of an item, the team in coordination with the Team BG arranges for shipment of the item to a storage installation.
Basis of Allocation: One or more as required per Theater Engineer Supply Control Office.

Capabilitics: Provides engineer lield maintenance support for approximately 140 major items of engincer construction cquipment or 90 vchicle equivalents.
Basis of Allocation: Normally one per special task foree requiring a maintenance force of less than a platoon of an engineer field maintenance eompany or larger maintenanee team. mately 375 major items of engineer eonstruetion equipment or 180 vehicle cquivalents.
Basis of Allocation: Normally one per special task force requiring a force of less than a platoon of an engineer field maintenance eompany or to augment an engineer field maintenanee company.

| Designation | Name | Authorized strength |  |  |  | Capabilities and basis of allocation |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | Em | Total |  |
| EC. | Special equipment maintenance. | 0 | 0 | 8 | 8 | Capabilities: Provides technically qualified personnel to operate a mobile machine shop for the repair of special engineer equipment, including sniperscopes, mine detectors, odographs, searchlights, and small quantities of other infrared deviccs, precision instruments, and similar items. Team is capable of maintaining approximatcly 1,050 sniperscopes, 700 mine detcctors, 25 odographs, 6 scarchlights, and miscellaneous items. <br> Basis of Allocation: Normally one per engineer field maintenance company where there is a high concentration of special engineer equipment. |
| ED.--.-.-- | Parts | 0 | 1 | 17 | 18 | Capabilities: Provides parts supply support for 1,500 major items of engincer equipment employed by an engineer forcc operating in an area which docs not require support of larger parts supply units. Team can issue approximately 3,000 linc items per month, and can store approximatcly 50 tons of repair parts or 9,000 line items. Basis of Allocation: Normally one per special task force or one per Engineer Field Maintenance Company, TOE 5-157; and as required to support Engineer Parts Depot Company, TOE 5-279, and Engineer Depot Maintenance Company, TOE 5-278. |
| EE. | Rcpair parts instructoradviser. | 0 | 1 | 4 | 5 | Capabilities: Provides technically qualificd personnel for advising, instructing, and rendering assistance to engincer and engincer equipment using units on repair parts problems such as interpretation of parts supply policics and procedures, procurement, distribution, supply and stock control, storage, utilization, disposition of excesses, and the recovery of reparable parts. |



Basis of Alloeation: To engineer supply control offices and similar organizations and Engineer Maintenance and Supply Group, TOE 5-262, as required.
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Capabilities: Provides qualified personnel and equipment to aeeomplish field maintenanee support of engineer equipment within AAA units.
Basis of Allocation: Normally one per AAA Group outside CONUS eomposed of two to four AAA Missile Battalions NIKE Semimobile TOE 44-145; AAA Battalion 75-mm Gun, Mobile TOE 44-15; AAA Battalion 120-mm Gun, Semimobile TOE 44-115.
Ciapabilities: Provides immediate field maintenanee service for the engineer equipment organic to the Ordnance Guided Missile Direet Support Company (CORPORAL) TOE 9-228, and three Field Artillery Missile Battalions, CORPORAL TOE 6-545. Sueh support will include repairing and/or replacing engines, assemblics of subassemblies, not above field maintenance level, maintaining balanced stocks of repair parts for use of organic maintenance persomel, receive and issue to supported units repair parts for organizational use, assemble and report, through engineer maintenanee channels, statistical data on supported engineer cquipment, inspecting organizational maintenance activitics, technical inspection of engineer equipment, and furnishing of advice on repair parts stock levels for organizational maintenance, and their storage and usage.
Basis of Allocation: Normally attached to the Ordnance Guided Missile Direct Support Company (CORPORAL) TOE 9-228.

4 Capabilities: Planning for overall strategie fire defense; eontrols firefighting teams assigned or attaehed.
Basis of Alloeation: Normally one per two to four firefighting teans and one water tank team.

| Designation | Name | Authorized strength |  |  |  | Capabilities and basis of allocation |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |
| FB. | Fire truek-------------- | 0 | 0 | 6 | 6 | Capabilities: Establishes organized fire protection and fire prevention programs in areas to which assigned; will provide fire protection for areas housing 5,000 to 10,000 troops, or warehouse and open stock pile storage of 100,000 square feet. <br> Basis of Allocation: One per post, base, camp, or station housing 5,000 to 10,000 troops, or warehouse and open storage area of 100,000 square feet. |
| FC. | Fire trailer | 0 | 0 | 1 | 1 | Capabilities: This team, ineluding team chief with volunteer personncl, will furnish fire protection to an area housing from 5,000 to 10,000 troops, or warehouse and open storage spaee of 100,000 square feet. Basis of Allocation: One per post, base, eamp, or station housing up to 5,000 troops, or warehouse and open storage area of 100,000 square feet when a firetruek team is not requircd. |
| FD. | Water tank $\qquad$ <br> EQUIPMENT OPERATING teams | 0 | 0 | 2 | 2 | Capabilities: Transport water for firefighting purposes when insuffieient water storage is available. <br> Basis of allocation: One per firefighting platoon; additional as required. |
| GA | Dump truek. | 0 | 0 | 13 | 13 | Capabilities: Provides supervisory personnel, drivers, and dump trucks for hauling bulk materials such as dirt, gravel, eoal, road metal, ete. Capaeity for hauling depends upon factors such as type of material, distanec per trip, and loading facilities. Maximum hauling eapaeity is 40 tons. |



Basis of Allocation: Normally attached to a dump truck eompany to augment its hauling capacity; may be attaehed to eonstruetion company or serviee units when required.
Capabilities: Provides personnel for the operation of the 50 tons per hour crushing and screening plant.
Basis of Alloeation: Normally attaehed to an engineer eonstruetion unit to furnish and operate equipment for production of crushed stone necessary for accomplishment of engineer construetion missions.
Capabilities: Provides personnel and equipment nceessary to conduct logging and sawmill operations for the production of rough lumber and timber piling. Capable of producing 10,000 to 15,000 board fect of rough lumber and timber piling per day.
Busis of Allocation: Normally attached to an engineer forestry company, but may operate independently when the employment of an engincer forestry company is not warranted.
Capabilitics: Provides supervisory personnel and equipment for drilling water wells; installs casings and pumps for wells to supply water to units or stations.
Basis of Allocation: Nornally attached to a construction unit which will provide additional persomel necessary for well drilling operations.
Ciapabilities: Provides persomnel and equipment for purifying up to 3,000 gallons of potable water per hour, and storage facilities for 12,000 gallons.
13asis of Allocation: Normally attached to a water supply eompany, but may operate independently when the employment of a water supply company is not warranted.
Designation

| GJ | Carbon dioxide generating. |
| :---: | :---: |
| GK | Quarrying and processing (Tentative). |
|  | CONSTRUCTION, UTILITIES, and electrical power teams |
| HA. | Port construction headquarters. |
| HB. | Diving- |
| HC. | Welding-- |

Capabilities: Provides necessary technically qualified personnel for the gencrating, storage, and transportation of carbon dioxide in gaseous and liquid form and in the form of dry ice. Unit operates machinery for the generation of hydrogen and carbon dioxide gases, and to store limited quantities of these gases.
Basis of Allocation: Normally one attached to the engineer maintenance and supply group.
Capabilities: Provides personnel and equipment for the operation of the 225 tons per hour crushing, scrcening, and washing plant. Provides necessary personnel and equipment for drilling and blasting operations required to produce raw stone for crushing.
Basis of Allocation: To Engineer Heavy Construction Battalion, TOE 5-355, as required.

Capabilities: Provides technically qualificd persomel to augment an engincer staff section or unit for the performance of specialized phascs of port plaming, such as capacity, layout, site sclection, design, matcrial requircments, and special cquipment needs.
Basis of Allocation: Normally onc per engineer group when engaged in major port projects.
Capabilities: Provides personnel and cquipment to perform marinc diving in support of port construction and rehabilitation and other types of enginecr construction, including underwater pipclines which may require diving personnel and equipment.
Basis of Allocation: Normally one per engineer group when engaged in major port or underwater pipeline projects.
4 Capabilitics: Provides technically qualified welders and equipment for attachment to units where the organic personnel and equipment arc inadequate.
Basis of Allocation: Normally one per engincer construction group and two per engineer maintenance and supply group.

| Designation | Name | Authorized strength |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |
| HD.----- | Utilities | 1 | 0 | 27 | 28 |
| HE. | Utilitics_ | 1 | 1 | 44 | 46 |
| HF-------- | Utilities_ | 2 | 1 | 52 | 55 |
| HG-..------ | Utilities. | 3 | 1 | 79 | 83 |

Capabilities and basis of allocation

Capabilities: Provides personncl and equipment for maintenance of utilities at installations up to 2,500 individuals; provides post engineer service to overseas or theater of opcrations installations; maintains utilitics and furnishes utilitics service and repair, including refrigeration maintenancc.
Basis of Allocation: Normally one per overseas camp, base, depot, or installations up to 2,500 individuals.
Capabilities: Provides personnel and equipment for maintenance of utilitics at installations up to 4,000 individuals; provides post engineer service in overscas or theater of operations installations; maintains utilities and furnishes utilities scrvice and repair, including refrigeration maintenance.
Basis of Allocation: Normally one per overseas camp, base, dcpot, or installations up to 4,000 individuals.
Capabilities: Provides personnel and equipment for maintenance of utilities at camps, bases, and depots for installations up to 6,000 individuals; provides post engineer scrvice in overseas or theater of operations installations; maintains utilities and furnishes utilitics service and repair, including refrigeration maintenance.
Basis of Allocation: Normally three in communications zone area per supported field army.
Capabilities: Provides personnel and equipment for maintenance of utilities at camps, bases, and depots for installations up to 10,000 individuals; provides post engineer service in overseas or theater of operations installations; maintains utilities and furnishes utilities scrvice and repair, including refrigeration maintenance.


Basis of Allocation: Normally one per typical field army and two in communications zone area per supported field army.
Capabilities: Provides technically qualificd personnel and tools for the installation of high voltage eleetric power lines, and the maintenance of approximately 60 miles of high voltage electrie power lines.
Basis of Alloeation: Normally one per two eleetrie power generating plants of 300 to $2,500 \mathrm{kw}$. capacity.
Capabilities: Provides technically qualified personnel and equipment for maintenanee of electric power generating plants of 300 to 2,500 kw. eapaeity, when welding team HC is attaehed, and furnishes supervisory personnel for construction and rehabilitation of such plants.
Basis of Alloeation: Normally one per two electric power generating plants of 300 to $2,500 \mathrm{kw}$. capaeity.
Capabilities: Provides technically qualified persomel for the operation of cleetrieal powerplants eontaining from one to thrce dicsel engine driven gencrators, capaeities of whieh range from 300 to $2,500 \mathrm{kw}$.
Basis of Allocation: Normally four per engineer brigade in eommunieations zone area.
Capabilitics: Provides teehnically qualified persomel for the oper- ation of one set of enginecr foundry equipment.
Basis of Alloeation: Normally one per engineer depot maintenanec eorhpany when foundry service is required.

Table 2. Engineer Teams-Continued
~


Capabilities and basis of allocation

Capabilities: When augmented by one mess tcam CA and two mess teams CB from TOE 29-500, this unit is capable of 24 -hour operation for extended periods at full rated load; providing continuous 3 -phase, 60 -eyele, electrie power in quantities up to $34,500 \mathrm{kw}$. at output voltages between 13,800 and 115,000 volts; supplying eleetrie power to eivilian or military installations near shore, harbor, or navigable stream at proper voltages by means of variable step-up transformers; supplying eleetrie power to shore and inland areas by means of eonneetion to existing transmission lines. Capable of routine and emergeney maintenance and minor repairs of equipment by assigned personnel. Towing vessel is required to move this ship.
Basis of Alloeation: As required in theater of operations, communications zone, and \%one of interior.
Capabilities: Provides cleetrie power for direet support of our Armed Forees and to meet any critieal electrical requirements of civilians in occupied eountries; to provide suffieient electrical power for military installations, industrial plants, or limited population centers at proper voltages through variable step-up transformers; to incet varying foreign and domestie situations of either 50 - or 60 -eyele eurrent under a wide variety of output voltages; supply elcetrieal power to areas by means of eonneetion to existing transmission lines; eapable of 24 -hour operation for extended periods at full rated load with powerplant operations to be carried on by assigned personnel; capable of routine and emergeney maintenance and minor repairs of equipment by assigned personnel. Unit is not self-propelled and a towing engine must be furnished.
Basis of Allocation: As required in theater of operations and zone of interior.


Capabilities: Provides personnel and equipment for the employment of the Decoy Target Gun 280-mm. w/Carriage Medium Fidelity Pneu w/Carrying Case in a theater of operation.
Basis of Allocation: Normally one per 280 mm . Gun, Field Artillery Battalion in the theater of operations. As required when other deception operations are contemplated.

Capabilitios: Provides technically qualified personnel and equipment for the survey operations of one party.
Basis of Allocation: Normally one per engineer brigade.
Capabilities: Provides teehnically qualified personnel and equipment for threc survey partics, and limited preparation of map mannseript.
Basis of Allocation: Normally attached to Engincer Base Survey Company, TOE $5-348$, when mapping operations require additional effort but less than a base survey company.
Capabilities: Provides technieally qualified personnel and equipment for the preparation of topographic maps by multiplex methods from aerial photographs.
Basis of Allocation: Normally attached to Engincer Basc Photomapping Company, TOE 5-349, when mapping operations require additional effort but less than a base photomapping company.
Capabilities: Provides technically qualified personnel and equipment for the production of maps from original manuserips, and limited quantitics of photostats.
Basis of Allocation: Normally attached to Engineer Base Map Reproduction Company, TOE 5-347, when mapping operations require additional effort but less than a base map reproduction company.
Table 2. Engineer Teams-Continucd

| Designation | Name | Authorized strength |  |  |  | Capabilities and basis of allocation |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |
| IE. | Map depot platoon | 1 | 0 | 38 | 39 | Capabilities: Provides technically qualified personnel and equipment for the receipt, storage, issue, and distribution of maps of a base, army, or corps headquarters. Platoons can operate as a depot. Basis of Allocation: Normally three per army topographic battalion for forward depots. |
| IF. | Relief-map making | 0 | 1 | 17 | 18 | Capabilities: Provides technically qualified personnel and equipment to construct original terrain models at scales from 1:5,000 through 1:50,000, and produce quantities of plastic reproduction at these scales. <br> Basis of Allocation: Normally one per base topographie battalion. |
| IG_. | Technical intelligence collection. | 3 | 0 | ${ }^{6}$ | 9 | Capabilities: Provides technically qualified personnel and equipment for finding, collecting, identifying, photographing, and reporting on elements of engineer technical intelligence, such as: foreign engineer materiel (equipment), construction, organization, training, tactics, techniques, installations, and fortifications; also illustrating and preparing training aids and instruction in the use of, or counteracting enemy engineer material. <br> Basis of Allocation: Normally one per corps. |
| IH. | Tcchnical intelligence, research. | 5 | 0 | 8 | 13 | Capabilities: Provides technically qualified personnel and equipment for collecting, receiving, evaluating, photographing, and reporting on elements of engineer technical intelligence, such as: engineer material, construction, organization, training, tactics, techniques, installation fortifications, and research and development, illustrating and preparing training aids of items of engineer intelligence. Assists with the interrogation of enemy military and civilian persomnel for engineer intelligence, and coordinates the activities of engineer technical intelligence teams IG (Collection). <br> Basis of Allocation: Normally one per field army. |



Capabilitics: Provides technically qualified personnel for instruction and/or supervision of units engaged in high-order geodetic surveys and computations as required in a theater of operations survey program and as otherwise required in the field army for guided missilc support.
Basis of Allocation: One per theater of operations and normally one per ficld army when required.
Capabilitics: Provides technically qualified personnel and equipment for the collection, c valuation, and dissemination of terrain data; the production of terrain studies; and provision of consultant services in military gcology and military hydrology
13asis of Allocation: Normally one per army but may be assigned at a lower level.
Capabilitios:
a. Map program planning and technical supervision of map compilation; surveying and gcodetic activitics including supervision, collection, maintenance and dissemination of survey control data; supervision and coordination of map reproduction including evaluation of reproduction facilities and planning the employment of such facilitics in the map reproduction program; supervision of the topographic and map supply program; including operation of map depots and supply points throughout the command. Maintains liaison with higher headquarters and allicd armies. Supervise non-United States indigenous reproduction and mapping agencies used in the program.
b. Transportation will be provided by area motor pools, or organization to which attached.
Basis of Allocation: Onc per theater, army group, field army headquarters, or base topographic battalion as required.
Capabilities: Provides technically qualified personnel and equipment for assisting photographic units in accomplishing acrial cartographic photography suitable for the compilation of military topographic maps, also the evaluation of such photography to detcrmine its suitability for the required purpose.

Table 2. Engineer Teams-Continued

| Designation | Name | Authorized strength |  |  |  | Capabillties and basis of allocatlon |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Off | wo | EM | Total |  |
|  | dredge crews |  |  |  |  | Basis of Allocation: As required, normally attached to Headquarters and Headquarters Detaehment, Engineer Base Topographie Battalion, TOE 5-346. |
| JA. | 20-ineh-eutter pipeline dredge. | 4 | 6 | 48 | 58 | Capabilities: When augmented by labor personnel from TOE 10-67 or other available labor sourees and a minimum of one mess team CA and one mess team CB from TOE 29-500, this unit provides personncl for the operation and maintenance of the engineer dredge, nou-self-propelled, diesel powered, 20 -ineh-eutterhead type, pipeline. <br> Basis of Allocation: As required. |
| JB.- | 24-inch-eutter pipcline dredge. | 3 | 6 | 38 | 47 | Capabilities: When augmented by labor personnel from TOE 10-67 or other available labor sourees, and a minimum of one mess tcam CA and one mess team CB from TOE $29-500$, this unit provides personnel for the operation and maintenance of the engineer dredge, turbine powered, 24-inch-cutterhead type, non-self-propelled, pipeline. <br> Basis of Alloeation: As required. |
| JC-- | 700-cubie-yard dieselelectric seagoing hopper dredge. | 5 | 4 | 39 | 48 | Cupabilities: When augmented by a minimum of one mess team CA and one mess team CB from TOE 29-500, this unit provides personnel for the operation and maintenance of the engincer dredge, seagoing hopper, diesel electrie powered, 700 eubie yard. <br> Basis of Allocation: As required. |



## CHAPTER 3

## LOGISTICAL DATA

## Section I. EQUIPMENT OTHER THAN MOTORIZED

## 6. Engineer Equipment

Table 3 gives the nomenclature, dimensions, cubages, and weights of sets of engineer equipment and engineer equipment chests.

Table 3. Sets of Engineer Equipment

| SM. 5-4 | Nomenelature | $\underset{(\text { (in.) }}{\text { Length }}$ | width <br> (in.) | $\underset{(\text { In.) }}{\substack{\text { Height }}}$ | Cu. Ft. | Welght (lb.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1080-S01 | CAMOUFLAGE TRAINING SET: Aviation Engineer |  |  |  | 879.0 | 15. 150. 0 |
| 1080-S02 | CAMOUFLAGE TRAINING SET: Company |  |  |  | 326.9 | $0$ |
| 1080-S03 | CAMOUFLAGE TRAINING SET: General Purpos |  |  |  | 284. 6 | 3, 000. 0 |
| 1080-S04 | CAMOUFLAGE TRAINING SET: Maintenance_ |  |  |  | 102. 0 | 1,597. 0 |
| 1080-S05 | CAMOUFLAGE NET SET: Single Engine Aireraft |  |  |  | 102. 80, | $\begin{aligned} & 1,597.0 \\ & 1,271.0 \end{aligned}$ |
| 1080-S06 | CAMOUFLAGE NET SET: Antiaircraft Machinegın, 50 Caliber. |  |  |  | 6.0 | 1, 2714.0 |
| 1080-S07 | REPAIR EQUIPMENT: Pneumatic Target, Sct No. 8. |  |  |  | 6. 6 | 180.0 |
| 1080-S08 | CAMOUFLAGE NET SET: Field Artillery, Drape Type |  |  |  | 179. 0 | 1, 904. 0 |
| 1080-S09 | CAMOUFLAGE NET SET: Field Artillery, Drape Type, $75-\mathrm{mm}$. Gun, $105-$ and $155-\mathrm{mm}$. Howitzers and Scr 784. |  |  |  | 65.0 | 997.0 |
| 1080-S10_ | CAMOUFLAGE NET SET: Antiaireraft Gun, Drape Type, $40-\mathrm{mm}$. Gun. |  |  |  | 362. 0 | 573. 0 |
| 1080-S11 | CAMOUFLAGE NET SET: Antiaircraft Machinc Gun, Drape Type, 50-Caliber Gun. |  |  |  | 32.5 | 527.0 |
| 1080-S12. | CAMOUFLAGE NET SET: Antiaircraft Gun, M2, U/W $105-$ and $155-\mathrm{min}$. Gun. |  |  |  | 44. 0 | 930.0 |
| 1080-S13. | CAMOUFLAGE NET SET: Antiaircraft Gun, M2, U/W $40-\mathrm{mm}$. Gun. |  |  |  | 17.0 | 412.0 |
| 1080-S14 | CAMOUFLAGE NET SET: Antiaircraft Gun M2, U/W $90-\mathrm{mm}$. Gun. |  |  |  | 17. 0 | 412.0 |
| 1080-S15 | CAMOUFLAGE NET SET: Field Artillery |  |  |  | 43. 5 | 968.0 |
| 1080-S16 | CAMOUFLAGE NET SET: Twin Engine Fighter Aireraft. |  |  |  | 95.0 | 2, 000.0 |
| 1080-S17 | CAMOUFLAGE NET SET: Antiaireraft Gun, U/W $120-\mathrm{mm}$. Gun. |  |  |  | 38.2 | 1, 411.0 |
| 1080-S18 | COVER, SHADE: Bomber Aircraft |  |  |  | 200.0 | 4, 800. 0 |
| 1080-S19 | COVER, SHADE: Fighter Aircraft, |  |  |  | 50.0 | 1, 150. 0 |


| SM 5-4 | Nomenclature | $\underset{\text { (in.) }}{\text { Length }}$ | Width (in.) | $\underset{\text { (in.) }}{\text { Height }}$ | Cu. Ft. | Welght (li.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1095-S01 | MINE PLANTING EQUIPMENT: Mechani |  |  |  | 6, 125. 0 | 61, 200.0 |
| 2090-S02 | CONSTRUCTION OUTFIT: Raft, Infantry Support |  |  |  | 813.0 | 9, 912. 0 |
| 2090-S04 | REPAIR EQUIPMENT: Plywood Boat and Ponton_ |  |  |  | 6.1 | 218.0 |
| 2090-S05 | REPAIR KIT: Inflatable Craft |  |  |  | 77.0 | 1, 200. 0 |
| 2909-S06 | REPAIR KIT: Aluminum Craft |  |  |  | 14.6 | 23.6 |
| 2090-S07 | REPPAIR EQUIPMENT: Plastic Assault Boat |  |  |  | 2. 0 | 110. 0 |
| $3220-\mathrm{S01}$ | SHOP EQUIPMENT, WOODWORKING, Base Maintenance. |  |  |  | 250.0 | 4, 800.0 |
| 3220-S02 | SHOP EQUIPMENT, WOODWORKING, Base Maintenance, Trailer Mounted. |  |  |  | 699. 0 | 6,100. 0 |
| 3424-S01 | SHOP EQUIPMENT: Forge, Base Maintenance |  |  |  | 1, 967.0 | 36, 215. 0 |
| 3428-S01 | SHOP EQUIPMENT: Base Maintenance, Foundry |  |  |  | 3,650. 0 | 108, 400. 0 |
| 3449-S01 | SHEET METALWORKING SET: Machine, Set 2 |  |  |  | 350.0 | 74, 000. 0 |
| $3470-\mathrm{S02}$ | SHOP EQUIPMENT: Machine, Shop, Base Maintenance |  |  |  | 3,590.0 | 75, 000. 0 |
| 3540-S01 | PRESERVATION AND PACKAGING EQUIPMENT <br> SET: Unmounted. |  |  |  | 576. 0 | 17, 500. 0 |
| 3540-S01 | PRESERVATION AND PACKAGING EQUIPMENT SET: Mounted on 6-ton Semitrailer. |  |  |  | 2, 395. 0 | 28, 000. 0 |
| 3610-S01 | REPRODUCTION SET: Ammonia Process |  |  |  | 75.0 | 790.0 |
| 3610-S02 | REPRODUCTION SET: Black and White Process |  |  |  | 10.0 | 230.0 |
| 3610-S05 | REPRODUCTION SET: Spirit Process, $221 / 2$ by 29 in |  |  |  | 93.9 | 800. 0 |
| 3610-S06 | REPRODUCTION SET: Ammonia Process, Continuous Tone. |  |  |  | 220.0 | 3, 800. 0 |
| 3610-S07 | REPRODUCTION SET: Topographic, Photolithographic. |  |  |  | 2, 130.0 | 23, 233. 0 |
| 3610-S13 | REPRODUCTION SET: Silk Screen Process |  |  |  | 19.0 | 619. 0 |



Table 3. Scts of Engineer Equipment-Continued

\begin{tabular}{|c|c|c|c|c|c|c|}
\hline SM 5-4 \& Nontenelature \& $$
\begin{gathered}
\text { Length } \\
(\mathrm{InI.)}
\end{gathered}
$$ \& $$
\begin{gathered}
\mathbf{W}_{1} \text { dth } \\
(\mathrm{in} .)
\end{gathered}
$$ \& $$
\begin{aligned}
& \text { Height } \\
& \text { (in.) }
\end{aligned}
$$ \& $\mathrm{Cu} . \mathrm{Ft}$. \& Weight (lb.) <br>
\hline 3820-S10 \& CRUSHING, SCREENING AND WASHING PLAN'T: Gasoline and Electric Driven, 225 tons per hr. \& \& \& \& $36,000.0$ \& 420, 000. 0 <br>
\hline 3830-S01 \& MAGNITT, SWEEPER, ROAD \& \& \& \& 160.0 \& 6,500. 0 <br>
\hline 3835-S10 \& PIPELINIE EQUIPMENT SET: For $21 / 2$-ton truck \& \& \& \& 462. 0 \& 4, 266.0 <br>
\hline 3835-S25 \& PIPELINE CONSTRUCTION ISQUIPMENT: Truck Mounted. \& \& \& \& 1, 120. 0 \& 16, 240.0 <br>
\hline 3895-S01 \& ASPHALT, MIXING AND PAVING SET: 80 tons per hre. \& \& \& \& 22, 100.0 \& 350, 000. 0 <br>
\hline 3895-S02 \&  \& \& \& \& 185. 0 \& 4, 200. 0 <br>
\hline 4210-S01 \& FIRE FIGHTING EQUIPMENT SET \& \& \& \& 153. 0 \& $5,398.0$ <br>
\hline 4210-S02 \& FIRE FIGHTING EQUIPMENT SET \& \& \& \& 173. 3 \& 3, 340. 0 <br>
\hline $4210-\mathrm{S03}$ \& FIRE FIGHTING EQUIPMENT SET: Set 3 Pumper 400 g.p.m., W/Trailer, Overscas. \& \& \& \& 557.0 \& 9, 123. 0 <br>
\hline 4210-S04 \& REPAIR AND REFILLING KIT: Carbon Dioxide Fire 1Extinguisher. \& \& \& \& 3. 0 \& 80. 0 <br>
\hline 4210-S05 \& FIRE FIGHTING EQUIPMENT SET: Truck Mounted, Zone of Interior. \& \& \& \& 1, 237. 3 \& $13,232.0$

$22,700.0$ <br>
\hline 4210-S09 \& FIRE FIGHTING EQUIPMENT SET: Sct 18, W/Truck, Overscas. \& \& \& \& 1, 880.0 \& 22, 700.0 <br>
\hline 4210-S11 \& FIRE FIGHTING EQUIPMENT SET: W/Truek, Guided Missile. \& \& \& \& 9.0
960.0 \& 29.0
$7,700.0$ <br>
\hline 4210-S12 \& FIRE FIGHTING EQUIPMENT SET: W/Trailer, Guided Missile. \& \& \& \& 960.0 \& 7, 700. 0 <br>
\hline 4210-S13 \& Fire fighting EQUIPMENT SET: W/Truck and Trailer Redstone Missile. \& \& \& \& N/A \& 60,000.0 <br>
\hline 4210-S14 \& FIRE FIGHTING EQUIPMENT SET: Sct 21, W/Truck, Army Aircraft Crash. \& \& \& \& 1, 760.0 \& 21,000. 0 <br>
\hline
\end{tabular}

| 4210-S15 | FORCED ENTRY AND RESCUE EQUIPMENT SET: Aircraft Crash. |  |  |  | 47. 0 | 340.0 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 4220-S01 | DIVING EQUIPMENT SET: 2 Persons, 200-foot Depth.- |  |  |  | 234.0 | 8,219.0 |
| 4220 -S02 | DIVING EQUIPMENT SET: 2 Persons, 100-foot Depth.- |  |  |  | 29.0 | 711.0 |
| 4220-S04 | DIVING EQUIPMENT SET: Laru, 1 Person, 30 -foot Depth. |  |  |  | 4.5 | 130.0 |
| 4320-S01 | PUMP ASSEMBLY: Rotary, Power Driven, ENG Well Development and Production Set 1. |  |  |  | 790.0 | 24, 882.0 |
| 4320-S02 | PUMP ASSEMBLY: Rotary, Power Driven, ENG Well Development and Production Set 2. |  |  |  | 613.9 | 16,515. 0 |
| 4610-S01 | WATER PLANT: EQUIP MENT SET: 900 gal. per hr- |  |  |  | 254.0 | 4, 136.0 |
| 4610-S02. | WATER PURIFICATION EQUIPMENT SET: 2,100 gal. per hr. |  |  |  | 262.0 | 5, 158.0 |
| 4610-S03 |  |  |  |  | 695.0 | 9, 610. 0 |
| 4610-S06 | FILTER UNIT: Water Purification, Knapsack Type, $1 / 4$ g.p.m. Hand Driven. |  |  |  | 4.5 | 62.0 |
| 4620-S02 | DISTILLATION EQUIPMENT SET: Water, Trailer Mounted, 60 gal. per hr. |  |  |  | 665.2 | 6,775.0 |
| 4620-S06 | DISTILLATION EQUIPMENT SET: Water, Skid Mounted, 150 gal. per hr. |  |  |  | 380.0 | 8,900. 0 |
| 4940-S03 | SHOP EQUIPMENT: Base Maintenance, Electrical Repair- |  |  |  | 224.0 | 5, 720.0 |
| 4940-S06 | SUPPLEMENTARY EQUIPMENT: Heavy Shop Company. |  |  |  | 545.0 | 47, 100.0 |
| 4940-S07 | SUPPLEMENTARY EQUIPMENT: Maintenance Company. |  |  |  | 523.2 | 17, 650.0 |
| 4940-S08 | GENERAL PURPOSE REPAIR SHOP EQUIPMENT: Base Maintenance. |  |  |  | 1,659.0 | 29,602.0 |
| $4940-\mathrm{S} 09$ | TOOLROOM EQUIPMENT: Heavy, Base Maintenance.-- |  |  |  | 192. 0 | 7, 422.0 |
| 4940-S11 | SHOP EQUIPMENT: General Purpose Repair, Semitrailer Mounted. |  |  |  | 1,910.0 | 22, 700.0 |

Table 3. Sels of Engineer Equipment-Continued

| SM 5-4 | Nomenclature | Length <br> (in.) | width (in.) | $\underset{\text { (in.) }}{\text { Height }}$ | $\mathrm{Cu} . \mathrm{Ft}$. | Welght (lb.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 4940-S12 | SHOP EQUIPMENT: Organizational Repair, Light, Truck Mounted. |  |  |  | 2, 230.0 | 22, 120.0 |
| 4940-S13 | SHOP EQUIPMENT: Contact Maintenance, Truck Mounted. |  |  |  | 906.0 | 8,980. 0 |
| 4940-S14. | SHOP EQUIPMENT: Electrical Repair, Semitrailer Mounted. |  |  |  | 2, 296.8 | 20,600. 0 |
| 5180-S01 | ERECTION OUTFIT: High Bolted Storage Tanks_ |  |  |  | 96. 0 | 2,700. 0 |
| 5180-S02 | TOOL KIT: Supplemental, Pipeline Pump Station |  |  |  | 2. 0 | 80.0 |
| 5180-S03 | ERECTION OUTFIT: Low Bolted Storage Tanks |  |  |  | 1. 5 | 70.0 |
| 5180-S04 | TOOL KIT: Carpenter's Engineer Squad |  |  |  | 17. 0 | 330.0 |
| 5180-S05 | TOOL KIT: Carpenter's Engineer Platoon |  |  |  | 8. 0 | 230. 0 |
| 5180-S06 | TOOL KIT: Carpenter's Set 3, Engineer Combat Platoon, w/ease. |  |  |  | 5. 0 | 132. 0 |
| 5180-S08 | TOOL KIT: Sheet Metal Worker's |  |  |  | 7. 0 | 176. 0 |
| 5180-S09 | TOOL AND EQUIPMENT KIT: Pioneer, M-4 Floating Bridge, Set 5. |  |  |  | 34.0 | 1, 245. 0 |
| 5180-S11 | INTRENCHING OUTFIT: Infantry |  |  |  | 250. 0 | 4, 650. 0 |
| 5180-S13 | PNEUMATIC TOOL OUTFIT: Set 1 |  |  |  | 128.3 | 3, 040.0 |
| 5180-S15 | TOOL KIT: Pioneer, Engineer Combat Platoon |  |  |  | 12.0 | 325. 0 |
| 5180-S16 | TOOL KIT: Pioneer, Engineer Platoon, Set 2. |  |  |  | 221.0 | 2, 075.0 |
| 5180-S17 | TOOL KIT: Pioneer, Engineer Squad |  |  |  | 26. 0 | 752. 0 |
| 5180-S18 | TOOL KIT: Pioneer, General Utility |  |  |  | N/A | N/A |
| 5180-S19 | TOOL KIT: Mason and Concrete Finisher's. |  |  |  | 7. 6 | 103. 0 |
| 5180-S20 | TOOL KIT: Tractor, Base Maintenance, Set 8 |  |  |  | 4. 7 | 351. 0 |
| 5180-S22 | TOOL KIT: Blacksmith's, General |  |  |  | 29.0 | 1, 160.0 |
| 5180-S23 | TOOL KIT: Diesel Injector Repair, Set 9 |  |  |  | 2. 6 | 62.0 |
| 5180-S24 | TOOL KIT: Rigging, Wire Rope. |  |  |  | 3.5 | 167. 0 |



Table 3. Sets of Enyineer Equipment-Continued

| SM 5-4 | Nomenclature | $\begin{aligned} & \text { Length } \\ & \text { (in.. } \end{aligned}$ | $\begin{aligned} & \text { Width } \\ & (\ln .) \end{aligned}$ | $\begin{aligned} & \text { Height } \\ & \text { (in.) } \end{aligned}$ | $\mathrm{Cu} . \mathrm{Ft}$. | Welght (lb.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 5420-S17 | BRIDGE, FIXED: Steel, Highway, 60 ft lg. of Span, Semipermanent. |  |  |  | 892. 0 | 45, 800. 0 |
| 5420-S18 | BRIDGE, FIXED: Highway, 90 ft . Ig. of Span, Semipermanent. |  |  |  | 1, 944. 0 | 61,600.0 |
| 5420-S20 | BRIDGE, FIXED: Steel, Railway, 17 ft . lg. of Span_ |  |  |  | 66.6 | 5, 104. 0 |
| 5420-S21 | BRIDGE, FIXED: Steel, Railway Type, 21 ft . Ig. of Span I-Beam. |  |  |  | 160.0 | 8,655. 0 |
| 5420-S22 | BRIDGE, FI XED: Railway, 27 ft . lg. of Span |  |  |  | 205. 2 | 11, 518. 0 |
| 5420-S23 | BRIDGE, FIXED: Railway, 31 ft . lg. of Span |  |  |  | 339.8 | 18,568. 0 |
| 5420-S24 | BRIDGE, FIXED: Railway, 35 ft . lg. of Span |  |  |  | 382.2 | 20, 835. 0 |
| 5420-S25 | GIRDER SPLICING SET: Fixed Bridge, I-Beam, 25 |  |  |  | 1. 6 | 202.0 |
| 5420-S26 | GIRDER SPLICING SET: Fixed Bridge, I-Beam, 19 in |  |  |  | 1. 5 | 150. 0 |
| 5420-S27 | BRIDGE, FIXED: Railway Type, 123 ft . lg. of Span, Through Truss. |  |  |  | 5, 240. 0 | 273, 324. 0 |
| 5420-S28 | bridge conversion set: Fixed Bridge, Steel, Railway, Set A. |  |  |  | 20.0 | 3, 360.0 |
| 5420-S29 | BRIDGE CONVERSION SET: Fixed Bridge, Through Truss |  |  |  | 53.6 | 3,549. 0 |
| 5420-S30 | BRIDGE CONVERSION SET: Fixed Bridge - |  |  |  | 5. 5 | 353. 0 |
| 5420-S31 | BRIDGE CONVERSION SET: Fixed Bridge, Through Truss. |  |  |  | 8. 0 | 531. 0 |
| 5420-S32 | BRIDGE CONVERSION SET: Fixed Bridge, Through Truss. |  |  |  | 1,271. 0 | 69, 679. 0 |
| 5420-S33 | BRIDGE, FIXED: Railway, 70 ft .1 g |  |  |  | 1,797. 0 | 145, 338. 0 |
| 5420-S34 | BRIDGE, FIXED: 70 ft . lg. of Span, Through |  |  |  | 1,320.6 | 97, 361. 0 |
| 5420-S35 | BRIDGE CONVERSION SET: Fixed Bridge, Unit Construction. |  |  |  | 24.8 | 3, 773.0 |


${ }^{1}$ Total.

| SM 5-4 | Nomenclature | $\begin{aligned} & \text { Length } \\ & \text { (III.) } \end{aligned}$ | Width <br> (in.) | $\underset{\text { (in.) }}{\text { Height }}$ | $\mathrm{Cu} . \mathrm{Ft}$. | Weight (lb.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 5420-S65 | BRIDGE, FLOATING: Raft Seetion, Light 'Taetieal |  |  |  | 1, 600. 0 | 17, 250. 0 |
| 5430-S01 | TANK ASSEMBLY: Fabrie, Collapsible, 10,000 gal. eapaeity, for Petroleum. |  |  |  | 88.0 | 1, 455. 0 |
| 5450-S01 | TOIVIER ERECTION SET: Topographie, W/Tower.... |  |  |  | 426.0 | 8, 360.0 |
| 5850-S01 | SNIPERSCOPE, INFRARED: Set 1. |  |  |  | 5. 3 | 165.0 |
| 5850-S02. | EQUIPMENT REPAIR SET: Sniperseope Set 13 |  |  |  | . 1 | 3. 0 |
| 6210-S01 | SUPPLEMENTARY EQUIPMENT AIRCRAFT OPERERATIONAL AREA LIGHT SET: Heliport, Portable. |  |  |  | 14. 0 | 500.0 |
| 6210-S02_ | SUPPLEMENTARY EQUIPMENT AIRCRAFT OPERERATIONAL AREA LIGHT SET: Airfield Runway. |  |  |  | 35. 0 | 1, 200. 0 |
| 6210-S03. | LIGHT SET OPERATION AREA, AIRCRAFT: Set 6, $11 / 2 \mathrm{kw}$, Airfield Runway, Portable, Combat. |  |  |  | 80. 0 | 3, 000.0 |
| 6210-S04 | LIGHT SET, OPERATIONAL AREA, AIRCRAFT 1/2kw | 24. 0 | 19. 0 | 21. 0 | 5.5 | 96. 0 |
| 6230-S01 | IIGGHT SET: General Illumination, Set 2 | 54.4 | 42.8 | 31.0 | 41. 8 | 769.6 |
| 6230-S04 | LIGHT SET: General Illumination, Set $5,15 \mathrm{kw}$ | 107.0 | 76. 0 | 53.0 | 249.4 | 4, 050. 0 |
| 6230-S05 | FLOODLIGHT SET: Eleetrie, Portable, Mast Mounted |  |  |  | 40. 2 | 650.0 |
| 6230-S07 | FLOODLIGHT SET: Electrie, Portable. |  |  |  | . 6 | 26. 0 |
| 6230-S09 | SEARCHTIGHT SET: 60 in . dia. Refleetor | 252. 0 | 69.0 | 96. 0 | 966. 0 | 7, 325. 0 |
| 6230-S12 | LIGHT SET: Marker, Emergeney - |  |  |  | 5. 3 | 100. 0 |
| 6605-S01 | NAVIGATION SET: Land, Vehieular_ |  |  |  | 10. 0 | 162. 0 |
| 6605-S02. | NAVIGATION SET: Land, Vehieular. |  |  |  | 3. 0 | 64.0 |
| 6230-299-75 | SEARCHLIGHT: 18 in.; 26 v., 2,500 w.; Reflector, w/braekets for tank mtg. |  |  |  |  |  |
| 6630-S01 | WATER QUALITY CONTROL SET |  |  |  | 6. 0 | 125. 0 |
| 6630-S02 | TEST SET, SOIL: Set 1. |  |  |  | 58.0 | 1,611. 0 |
| 6630-S03 | TEST SET, ASPHALT: Set 12 |  |  |  | 140. 0 | 1, 455. 0 |
| 6630-S04 | TEST SET, CONCRETE: Set 13 |  |  |  | 51.0 | 1, 637. 0 |



| SM 5-4 | Nomenclature | $\begin{gathered} \text { Length } \\ \text { (in.) } \end{gathered}$ | $\begin{aligned} & \text { Width } \\ & \text { (in.) } \end{aligned}$ | $\underset{\substack{\text { Height } \\ \text { (in.) }}}{\substack{\text { Heghen }}}$ | Cu. Ft. | Welght (lb.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 6675-S32 | SURVEYING SET: Supplementary Equipment, Topographic Battalion. |  |  |  | 20.0 | 535. 0 |
| 6675-S37 | SURVEYING SET: General Purposc_ |  |  |  | 28. 0 | 474. 0 |
| 6675-S38 | SURVEYING SET: Planc table |  |  |  | 20. 2 | 260.0 |
| 6675-S39 | SURVEYING SET: Precise Basclinc, Set 9 |  |  |  | 10. 0 | 260. 0 |
| 6675-S40 | SURVEYING SET: Prccise Leveling |  |  |  | 2. 0 | 29.0 |
| 6675-S41 | SURVEYING SET: Prccise Traversing |  |  |  | 22.0 | 375. 0 |
| 6675-S42 | SURVEYING SET: Triangulation Reconnaissance |  |  |  | 5. 0 | 103. 0 |
| 6675-S43 | SURVEYING SET: Topographic Company |  |  |  | 187. 3 | 3,561. 0 |
| 6675-S44 | SURVEYING SET: Triangulation |  |  |  | 14.0 | 285.0 |
| 6675-S45 | SURVEYING SET: Artillery Fire Control 3d Order |  |  |  | 2. 0 | 260.0 |
| 6675-S46 | SURVEYING SET: Astronomic Azimuth |  |  |  | N/A | N/A |
| 6675-S47 | SURVEYING SET: Artillery Fire Control 4th Order |  |  |  | 2. 0 | 260.0 |
| 6675-S48 | MAP DISTRIBUTION SET: Portable |  |  |  | 230.0 | 4, 400. 0 |
| 6675-S49 | MAP DISTRIBUTION SET: Dcpot |  |  |  | 3, 615. 1 | 53, 250.0 |
| 6675-S50 | SURVEYING SET: Astronomic Azimuth, Sct 20....-.-. |  |  |  | 52.0 | 1,600. 0 |
| 6675-S51 | CARTOGRAPHIC SECTION: Topographic Mapping Set- |  |  |  | 2, 420.0 | 22, 260. 0 |
| 6675-S52 | COPY AND SUPPLY SECTION: Topographic Mapping Set. |  |  |  | 2, 420.0 | 23,580. 0 |
| 6675-S53 | RECTIFIER SECTION: Topographie Mapping Set.....- |  |  |  | 2, 420.0 | 23, 975. 0 |
| 6675-S54 | MAP REVISION SECTION: Topographic Mapping Sct.- |  |  |  | 2, 420.0 | 21, 475. 0 |
| 6675-S55 | MULTIPLEX SECTION: Topographic Mapping Set |  |  |  | 2, 420.0 | 24, 200. 0 |
| 5675-S56 | PHOTOMAPPING SECTION: Topographic Mapping Set. |  |  |  | 2, 420.0 | 21,680. 0 |
| 6675-S57 | SUPPLEMENTARY EQUIPMENT SET |  |  |  | 162. 0 | 4,550.0 |
| 6675-S59 | DRAFTING EQUIPMENT SET: Plastic Scribing. |  |  |  | 0. 2 | 10. 0 |
| 6675-S61 | SURVEYING SET: Missile Laying. |  |  |  | 18.0 | 240.0 |



Table 3. Sets of Engincer Equipment-Continued

| SM 5-4 | Nomenclature | $\begin{aligned} & \text { Length } \\ & \text { (in.) } \end{aligned}$ | $\begin{aligned} & \text { Width } \\ & \text { (in.) } \end{aligned}$ | $\underset{(\text { in. })}{\text { Height }}$ | Cu. Ft. | Weight (lb.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 9999-S06_ | SUPPLAEMENTARY EQUlPMENT: Depot |  |  |  | 545.0 | 47, 100. 0 |
| 9999-S07 | SUPPLEMENTARY EQUIPMENT: Aviation Battalion_ |  |  |  | 251.0 | 4, 819.0 |
| 9999-S08 | SUPPLEMENTARY EQUIPMENT: Separate Battalion |  |  |  | 330.0 | 5,900. 0 |
| 7610-S13 | BOOK SET: Set 14. | 19.3 | 13.8 | 11. 0 | 1.1 | 35. 0 |
| 7610-S14 | BOOK SET: Sct 15 | 17. 3 | 9.0 | 12. 3 | . 7 | 16.0 |
| 9905-S01 | MINEFIELD MARKING SET |  |  |  | 278.9 | 221.9 |
| 9999-S01 | SUPPLEMENTARY EQUIPMENT: Armored Battalion.. |  |  |  | 289.0 | ${ }^{2} 2,394.0$ |
| 9999-S02 | SUPPLEMENTARY EQUIPMENT: Camouflage Battalion. |  |  |  | ${ }^{2} 6,000.0$ | $217,500.0$ |
| 9999-S03 | SUPPLEMENTARY EQUIPMENT: Aviation Combat Battalion. | 132.0 | 60.0 | 57.0 | 261.3 | $6,300.0$ |
| 9999-S04 | SUPPLEMENTARY EQUIPMENT: Forestry Company - |  |  |  | ${ }^{2} 1,200.0$ | ${ }^{2} 30,500.0$ |
| 9999-S05 | SUPPLEMENTARY EQUIPMENT: Engineer Construction Battalion. |  |  |  | ${ }^{2} 234.0$ | ${ }^{2} 12,100.0$ |
| 9999-S06 | SUPPLEMENTARY EQUIPMENT: Depot |  |  |  | ${ }^{2} 545.0$ | ${ }^{2} 47,100.0$ |
| 9999-S07 | SUPPLEMENTARY EQUIPMENT: Aviation Battalion |  |  |  | ${ }^{2} 523.2$ | ${ }^{2} 17,650.0$ |
| 9999-S08 | SUPPLEMENTARY EQUIPMENT: Separate Battalion. |  |  |  | ${ }^{2} 330.0$ | ${ }^{2} 5,980.0$ |
|  | Chest: |  |  |  |  |  |
|  | Battery, lamp, electric, command post-------------- | 20. 5 | 17. 0 | 14. 5 | 2. 9 | 25.0 |
|  | Bearing ratio equipment.-.-- |  |  |  | ${ }^{2} 27.0$ | ${ }^{2} .118$ |
|  | Black and white printing equipment |  |  |  | ${ }^{2} 8.1$ | ${ }^{2} 82.0$ |
|  | Blacksmith, engineer. | 39. 0 | 17. 0 | 10.3 | 3.1 | 43. 0 |
|  | Boat and pontoon repair equipment | 31.0 | 20.8 | 12. 5 | 3. 4 | 40. 0 |
|  | Carbon tetrachloride | 39.5 | 14. 5 | 15.0 | 5. 0 | 46.0 |
|  | Carpenter, platoon | 42. 0 | 25.0 | 12.3 | 5. 4 | 61.5 |
|  |  | 41.5 | 25.0 | 12. 0 | 5. 4 | 86. 0 |
|  | Chain hoist, 1-ton |  |  |  | ${ }^{2} 4.2$ | ${ }^{2} 49.0$ |


| C |  |  |  |
| :---: | :---: | :---: | :---: |
| Chain hoist, 11/2-3-ton (2 hoists) | 40.5 | 20. 0 | 9. 0 |
| Delineation equipment. |  |  |  |
| Diving apparatus, helmet | 37.5 | 23. 5 | 19.0 |
| Diving apparatus outfit, ES | 27. 3 | 16. 3 | 10.3 |
| Diving apparatus outfit, NS | 47.3 | 23. 8 | 21. 0 |
| Drafting, battalion, eoast art | 47.0 | 25. 5 | 13. 0 |
| Drafting, battalion, engineer | 46. 0 | 33.3 | 12.0 |
| Drafting, regimental, eoast a | 45. 5 | 35. 0 | 13. 0 |
| Drafting and duplieating | 25.5 | 20. 0 | 93. 5 |
| Drafting set No. 8, FA flash range |  |  |  |
| Drafting set No. 9, FA sound range |  |  |  |
| Duplieating equipment, gelatin process | 28. 0 | 21.5 | 21. 0 |
| Duplieating equipment, gelatin proees | 25. 5 | 23.3 | 5. 8 |
| Duplieating equipment, gelatin proee | 36. 5 | 34.8 | 12. 5 |
| Electric lighting equipment, portable: Chest type A | 40.0 | 34.3 | 19.0 |
| Electrie lighting equipment, portable: Chest type $\mathrm{B}_{\text {- }}$ | 39.0 | 27.0 | 15. 0 |
| Electrie lighting equipment, portable: Chest type "d". | 34.0 | 19.0 | 14. 0 |
| Eleetrie lighting equipment, portable: Chest, $11 / 2-\mathrm{kw}$. aecessories |  |  |  |
| Flash point teste | 42.0 | 15. 5 | 15. 5 |
| Kit, repair, small pneumatic floats | 25.5 | 19.0 | 11. 3 |
| Kit, repair, pneumatie float: Chest A | 49.0 | 25. 5 | 19.0 |
| Kit, repair, pneumatic float: Chest | 32. 3 | 18. 5 | 15. 5 |
| Kit, repair, pontoon, plywood. |  |  |  |
| Kit, repair, pontoon, aluminum or steel | 31.0 | 20.8 | 12. 3 |
| Lamp, eleetric, portable, eommand post. |  |  |  |
| Map distribution, type 2. | 44.5 | 17.3 | 17. 3 |
| Minefield marking, set No. 2: Chest No. 1 |  |  |  |
| Minefield marking, set No. 2: Chest No. 2 |  |  |  |
| Minefield marking, set No. 2: Chest No. 3 |  |  |  |
| Misecllaneous bridge parts |  |  |  |


| 235.0 | 22.4 |
| ---: | ---: |
| 4.2 | 49.0 |
| 22.3 | 250.0 |
| 9.7 | 145.0 |
| 2.6 | 31.0 |
| 13.7 | 115.0 |
| 9.1 | 70.0 |
| 10.6 | 95.0 |
| 12.0 | 98.0 |
| 2.7 | 40.0 |
| 212.0 | 291.0 |
| 28.0 | 280.0 |
| 2.8 | 60.0 |
| 1.7 | 27.1 |
| 9.2 | 118.3 |
| 15.0 | 136.0 |
| 9.1 | 50.0 |
| 5.2 | 34.8 |
|  |  |
| $\mathrm{~N} / \mathrm{A}$ | $\mathrm{N} / \mathrm{A}$ |
| 5.8 | 85.0 |
| 3.1 | 30.0 |
| 13.7 | 55.0 |
| 5.4 | 55.0 |
| 23.4 | 240.0 |
| 3.4 | 54.0 |
| 21.4 | 214.0 |
| 8.0 | 70.0 |
| 24.6 | 260.0 |
| 24.2 | 255.0 |
| 26.8 | 256.0 |
| 29.6 | 266.0 |

[^0]| SM 5-4 | Nomenelature | $\underset{\text { (In.) }}{\substack{\text { Length }}}$ | $\underset{(\mathrm{in} .)}{\text { width }}$ | $\underset{(\text { in. })}{\text { ILeight }}$ | Cu. Ft. | Weight (b.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Chest-CContinued |  |  |  |  |  |
|  | Miscellancous equipment (soil testing) |  |  |  | 21.0 | ${ }^{2} 33.0$ |
|  | Navigation, set No. 1 |  |  |  | ${ }^{2} 4.9$ | ${ }^{2} 46.0$ |
|  | Outboard motor, 5 hp | 53.0 | 18. 0 | 18. 0 | 9.9 | 50.0 |
|  | Pioneer equipment, long | 68.5 | 22.0 | 20. 0 | 11.9 | 104. 0 |
|  | Pioneer equipment, short | 41. 3 | 16.8 | 18. 5 | 6. 5 | 73.0 |
|  | Pipefitting equipment. |  |  |  | ${ }^{2} 3.5$ | ${ }^{2} 53.0$ |
|  | Pneumatic tools (315 cfm), set No. 1: Chest No. 1 | 57.5 | 35.5 | 13. 5 | 16.0 | 120.0 |
|  | Pneumatic tools ( 315 cfm ), set No. 1: Chest No. 2. | 34.8 | 22.5 | 7. 8 | 3.5 | 52.0 |
|  | Pneumatic tools ( 315 cfm ), set No. 1: Chest No. 3 |  |  |  | 23.5 | ${ }^{2} 65.0$ |
|  | Pneumatic tools (315 cfm), set No. 1: Chest No. 4 |  |  |  | 26.4 | ${ }^{2} 115.0$ |
|  | Pneumatic tools ( 315 cfm ), set No. 1: Chest No. 5 | 35.8 | 35. 0 | 10. 5 | 7.6 | 58.0 |
|  | Pneumatic tools (315 cfm), set No. 1: Chest No. 6 | 34.8 | 23. 4 | 9.0 | 4. 2 | 46. 0 |
|  | Pneumatic tools ( 315 cfm ), set No. 1: Chest No. 7. | 34. 6 | 22. 3 | 9.0 | 4. 1 | 50.0 |
|  | Preumatic tools ( 55 cfm ), set No. 1: Chest No. 1 |  |  |  | ${ }^{2} 15.7$ | ${ }^{2} 110.0$ |
|  | Pneumatic tools ( 55 efm ), set No. 1: Chest No. 2 |  |  |  | 22.9 | 230.0 |
|  | Pneumatic tools ( 55 cfm ), set No. 1: Chest No. 3. |  |  |  | 22.4 | 235.0 |
|  | Pneumatic tools ( 55 cfm ), set No. 1: Chest No. 4. |  |  |  | 23.3 | 239.0 |
|  | Pueumatic tools ( 55 cfm ), set No. 1: Chest No. 5 |  |  |  | ${ }^{2} 3.3$ | 235.0 |
|  | Printing frame, 24 by 30 in . | 35.3 | 30.0 | 8. 0 | 5. 1 | 50.0 |
|  | Rigging equipment. | 34. 8 | 17. 0 | 9.5 | 3. 2 | 33. 3 |
|  | Sign painting equipment |  |  |  | 27.8 | ${ }^{2} 68.0$ |
|  | Sign reproduction kit_ | 31.5 | 25.8 | 9.5 | 3. 9 | 47.8 |
|  | Sign storage. | 38.0 | 19.0 | 19.0 | 7. 5 | (i0. 0 |
|  | Soil sampling equipment, field laboratory |  |  |  | 24.4 | ${ }^{2} 43.0$ |
|  | Soil testing equipment, ficld laboratory. |  |  |  | ${ }^{2} 1.0$ | ${ }^{2} 33.0$ |
|  | Surveying, set No. 2, FA flash range. |  |  |  | 27.5 | ${ }^{2} 68.0$ |



[^1]
## 7. Radio Facilities of Engineer Units

The radio sets available to or associated with enginecr troop units, with their frequencies, emissions, normal ranges, and normal usage, are listed in table 4. Common abbreviations used in radio nomenclature are as follows:
a.c.---.-- alternating current

AF_.....- audio frequency
AM ----- amplitude modulation
BA.-.-.-- battery
c.p.s_-.-- cycles per second
c.w.-.-.-. continuous wave
d.c.-.-...- direct current

FM _-.--- frequency modulation
f.s.-.----- frequency shift

GN.-...- generator
HF---.--- high frequency
HV.-.-.- high voltage
LF....... low frequency

LV ......-. low voltage
m.c.w_.. modulated continuous wave
RF_--.-. radio frequency
mc........ megacycles
revr---.-- receiver
RT_...-.-- receiver-transmitter
SW _-.-. sky wave
v.......-. volt

VF_......- voice frequency
w-.-.-.-- watt
xmtr_-... transmitter
f.s.k....-. frequency shift keying

Table 4. Radio Sets

| Radio sct, | Frequency (megacyelcs) | Emission and range (miles) | Normal use | Remarks |
| :---: | :---: | :---: | :---: | :---: |
| AN/PRC-6_ | 47.0-55.4 | Voicc: FM (1) | Combat and airborne company: brigade platoon and section; dismounted tactieal units. | It is shaped like a telephone, but it can bc shoulder-slung and operated with an attached handset. |
| AN/PRC-8. | 20.0-27.9 | Voice: FM (3)-(5) | Armored company, battle group and division level. | Man-carried field radio-for vehicle operation, amplifier-power |
| AN/PRC-9 | 27.0-38.9 | Voice: FM (3)-(5) | Artillery | supply AM-598/U required. |
| AN/PRC-10 | 38.0-54.9 | Voice: FM ${ }_{\text {------- }}$ | Infantry combat and airborne units. | Same as AN/PRC-8. |
| AN/GRC-3 RT-70/GRC_ | $20.0-27.9$ $47.0-58.4$ | Voice: FM Stationary (15). Moving (10). | Armored units - ------------- | Can be installed in truck, personnel carrier, tanks, utility ve- |
| R-108/GRC. | 20.0-28.0 | , |  | hieles, ete. |
| AN/GRC-4. |  |  | less auxiliary receiver $\mathrm{R}-108$ |  |
| AN/GRC-7. | $38.0-54.9$ $47.0-58.4$ | Voice: FM Stationary (15). <br> Moving (10). <br> Voice: FM (1). | Infantry units | GRC) <br> Can be installed in truck, personnel carrier, tanks, utility ve- |
| R-110/GRC | 38.0-55.0 | Volec. FM (1). |  |  |
| AN/GRC-8. |  |  |  | $(R C)$ |
| AN/GRC-9.. | 2.0-12.0 | AM-stationary: c.w. (30); m.c.w. (20). Voice (15). Moving: e.w. (20); m.c.w. (10). Voice (10). | Infantry and armored motorized elements, engineer eombat battalion. | GRC) <br> Ground or vehicle-operated twoway radiotelephone and radiotelegraph between stationary |
| AN/GRC-19_ | $\text { _ } 1.5-20.0 \text { _- }$ <br> revr .5-32.0. | AM-Voice (50). f.s., c.w. (75). Sky wave (150)(1500). | Division, corps and army, engineer combat battalion to higher headquarters and recomnaissance. | and moving radios. <br> Forward area vehicular set. Replaces SCR-193 and SCR-506. Provides eommunication between vehicles from vehicle to |

Table 4. Radio Sets-Continued
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Same as GRC-3, except RT70/GRC and remote-control or retransmission facilities are not provided.
Same as GRC-3, except RT70/GRC and remote-control or retransmission facilities are not provided.
Basically 2 AN/VRC-8's on single mounting.
Basically 2 AN/VRC-9's on single mounting. Normally used for relay or retransmission.
Basically 2 AN/VRC-10's on single mounting. Point-topoint, retransmission, or radio relay between artillery and infantry elements.
Mobile medium powered, long range, point to point, and ground to air. Equipment includes teletypewriter radio receiver and transmitter, perforator transmitter, frequency shift exciter, dual diversity converter, and associated items installed in a field type shelter mounted on a $23 / 2$-ton, 6 by' 6 cargo truck, with a 1-ton trailer on which a portable field powered unit is installed.
Same as GRC-19, with radioteletype facilities. Mounted in $3 / 4$-ton truck.

## 8. Equipment of Other Supply Services

Tables 5 through 9 give weights and cubages of major items of equipment supplied by services other than the Corps of Engineers, which are of especial interest to engineer units. Data are for crated items except in the case of Signal Corps equipment (table 9). For items of ordnance equipment not listed in table 7, sec paragraphs 10 and 30 .

Table 5. Chemical Equipmeni (Crated)

| Item | Cubic feet | Weight, pounds |
| :---: | :---: | :---: |
| Decontaminating Apparatus | 4. 35 | 37. 50 |
| Detector Kit, M9A2 | . 26 | 6. 25 |
| Mask, Gas, M11A1 | . 73 | 12. 33 |
| Mask, Protective Field, M9A1 | . 55 | 9. 33 |
| Respirator, Air, Dust. | . 02 | . 32 |
| Respirator, Air, Paint Spray | . 34 | 5. 83 |
| Water Testing Kit, M4 | 1. 30 | 55. 00 |

Table 6. Medical Equipment (Crated)


Table 7. Ordnance Equipment (Crated)

| 1tem | Cubie feet | Weight, pounds |
| :---: | :---: | :---: |
| Cabinct, Spare Parts Type III, C1B | 29. 75 | 378. 00 |
| Chain Asscmbly, Sgle Leg, $5 / 8 \mathrm{in}$. by 16 ft | . 50 | 70. 00 |
| Demounter, Pncumatic Tire, Hydraulic | 10.60 | 300.00 |
| Mount, Machine Gun, Cal. 30, M48, W/EQP | 2. 40 | 65. 00 |
| Mount, Machinc Gun, AA, Cal. 50, M63, W/EQP - - | 8.10 | 170. 00 |
| Mount, Tripod, Machine Gun, Cal. 30, M2, W/EQP- | 1. 90 | 25. 00 |
| Mount, Tripod, Machine Gun, Cal. 50, M3, W/EQP_ | 2.00 | 44. 00 |
| Mount, Tripod, Machinc Gun, 7.62 MM, M91 | 2. 00 | 40. 00 |
| Mount, Truck, Pedestal, M24A2 | 10. 60 | 253. 00 |
| Tool Kit, Armorers. | 2. 42 | 48. 00 |
| Tool Kit, Automotive Fucl and Elce Sys Rpmn. | 1. 61 | 22. 45 |
| Tool Kit, Electricians No. 1 | 4. 74 | 82. 28 |
| Tool Kit, Elcetricians No. 2 | . 35 | 13. 00 |
| Tool Kit, General Mechanics | 2. 00 | 69. 00 |
| Tool Kit, Instrument Repairman | 1. 81 | 50.36 |
| Tool Kit, Mctal Body Repairınan | . 76 | 37.50 |
| Tool Kit, Organizational Maintenance No. 1 Common. | 41. 70 | 858. 00 |
| Tool Kit, Organizational Maintenance No. 1 Supplemental | 36. 80 | 871.00 |
| Tool Kit, Organizational Maintenance No. 2 Com-mon- | 276.00 | 2, 425. 00 |
| Tool Kit, Organizational Maintenance No. 2 Supplemental. | 130.80 | 3, 076. 00 |
| Tool Kit, Organizational Maintenance Set No. 7 | 65.00 | 935.00 |
| Tool Set, Machinist | 1. 33 | 48. 00 |
| Tool Set, Organizational Maint Army Aircraft | 59. 00 | 930. 00 |

Table 8. Quartermaster Equipment (Crated)

| Item | Cubie feet | Weight, pounds |
| :---: | :---: | :---: |
| Bag, Water Sterilizing. | 1. 34 | 20. 40 |
| Bag, Ammunition_ | . 08 | 2. 00 |
| Calculating Machinc | 1. 04 | 35. 00 |
| Can, A-G, 10 gal. cap. | 1. 01 | 13.83 |
| Can, A-G, 24 gal. cap_ | 3. 32 | 26. 67 |
| Can, A-G, 32 gal. cap. | 4. 57 | 32. 33 |
| Can, Water, 5 gal | . 94 | 10. 00 |
| Chest, Music, Fiber | 2. 89 | 26. 00 |
| Cooking Outfit, 1 brı | 26 | 5. 17 |
| Desk, Field, type 11 | 4. 28 | 54. 00 |
| Duplicating Machine, Hand Opr | 12. 65 | 204. 00 |
| Duplicating Machine, Mtr. Dvn | 28. 63 | 326. 00 |
| Duplicating Machine, Spirit Proc | 2. 98 | 65.00 |
| Lantern, Gas, $11 / 2 \mathrm{pt}$. | . 64 | 9.37 |
| Machine, Computing, 10 Column | 3. 08 | 65. 00 |
| Paulin, Duck, OD, 20 by 40 ft | 4. 90 | 192. 00 |
| Paulin, Duck, OD, 12 by 17 ft | 1. 65 | 50. 67 |

Table 8. Ouartermaster Equipment (Crated)-Continued

| Item | Cubic feet | Welght, pounds |
| :---: | :---: | :---: |
| Range, Field, M1937B Pack | 18. 50 | 340. 00 |
| Roll, Commissary, Complete | 3. 49 | 65.00 |
| Safe, Field | 5. 89 | 185. 00 |
| Scale, Plat, 300 Jb . | 4. 08 | 134. 00 |
| Screen, Latrine, Complcte | 1. 42 | 45. 00 |
| Sling, Flagstaff . | . 19 | 3. 19 |
| Stencil Cutting Machine, 1 in | 11. 14 | 190. 00 |
| Steneil Outfit_ | . 51 | 65. 50 |
| Typewriter, Non-Ptbl, 11 in | 4. 13 | 76. 00 |
| Typewriter, Non-Ptbl, 14-15 in | 5. 21 | 60. 00 |
| Typewriter, Non-Ptbl, 18-19 in_ | 4. 90 | 80.00 |
| Typewriter, Non-Ptbl, 26-27 in_ | 8.39 | 125.00 |
| Typewriter, Ptbl w/carrying case | 1. 50 | 32. 00 |

Table 9. Signal Equipment (Uncrated)

| Item | Cubic feet | Weight, pounds |
| :---: | :---: | :---: |
| Amplifier, AM-598/U. | 0.94 | 35. 95 |
| Axle, RL-27 | 12 | 5. 50 |
| Battery, BB-50 | . 50 | 64. 00 |
| Camera, PH-324 | . 02 | . 94 |
| Camera, PH-691/U | . 46 | 15. 00 |
| Camera, KS-7 | 64. 00 | 292. 00 |
| Channel Alignment Indicator | . 02 | 1. 30 |
| Chest, BC-5 | 3. 78 | 35. 00 |
| Chest, CY-250/U | 6.58 | 35. 00 |
| Chest Set, H-12/GT | . 04 | 2. 22 |
| Chest Set, H-18/GT | . 20 | 3. 40 |
| Code Tr'ug Sct AN/GSC-T | 1. 31 | 40.00 |
| Coil, C-161 | . 13 | 3. 00 |
| Converter, M209 | 08 | 6. 00 |
| Electronic Multimeter TS-50 | 34 | 15. 00 |
| Emergency Switchboard SB- | . 09 | 2. 25 |
| Exposure Meter $\mathrm{PH}-260$ | 01 | 1. 00 |
| Flashlight MX-212/U | . 01 | . 50 |
| Flashlight MX-991/U | . 02 | . 06 |
| Frequency Meter SCR-211 | . 96 | 39. 50 |
| Hand Sct TS-10. | . 20 | 1. 90 |
| Head Sct HS-30 | . 04 | . 57 |
| Lincmen's Equipment TE-21 | . 96 | 21. 00 |
| Microphonc..- | . 01 | . 09 |
| Multimeter AN/PRM-15 | 12 | 5. 00 |
| Oscilloscope OS-8/U_ | . 43 | 14. 50 |
| Photo Equipment PH-383. | 10. 00 | 333. 00 |
| Power Unit PE-162 | 1. 91 | 56.00 |
| Radiac Meter IM-93/UD | . 01 | . 07 |
| Radio Set AN/GRC 9 | 17.00 | 135. 00 |

Table 9. Signal Equipment (Uncrated)-Continued

| Item | Cubre feet | Weight, pounds |
| :---: | :---: | :---: |
| Radio Set AN/PRC 10 | 1. 37 | 18. 00 |
| Radio Sct AN/PRC 6 | . 16 | 3. 50 |
| Radio Set AN/VRC 10 | 3. 09 | 138.00 |
| Radio Set AN/VRC 8 - | 3. 09 | 138. 00 |
| Radio Set AN/VRC 16 | 3.'09 | 138.00 |
| Radio Set SCR-193. | 3. 60 | 114.00 |
| Radio Set AN/GRA | . 98 | 17. 50 |
| Radio Receiving Set AN/TRR-8 | 2. 43 | 26.00 |
| Reel Equipment CE-11. | 1. 13 | 17. 00 |
| Reel Unit RI-31 | 5. 00 | 100.00 |
| Spool DR-8. | . 38 | 2. 00 |
| Switch Board SB-22/PT | 2. 56 | 37. 10 |
| Telephone Set TA 264/PT | 66 | 25. 00 |
| Telephone Set TA 312/l'T | 9. 50 | 18 |
| Telephone Central Office Set TC-4 | 18.64 | 440.40 |
| Teletypewriter Set AN/PGC-1 | 20.00 | 451.00 |
| Terminal Telegraph | . 91 | 51.00 |
| Test Set TS-26/TSM | . 23 | 8.00 |
| Test Sct Electron Tube TV-7/U. | . 46 | 18. 00 |
| Timer Interval FM 17 | . 07 | 2. 00 |
| Tool Equipment TE 33 | . 03 | 3. 00 |
| Tool Equipment TE 41 | . 52 | 16. 00 |
| Tool Equipment TK 28/GF | . 80 | 17. 00 |
| Tube Tester | . 44 | 41.00 |
| Vibrator Pack PP-68/U | . 40 | 22. 00 |
| Wire pike | . 50 | 6. 00 |
| Wire WD-1/TT on Reel DR-4. | 1. 94 | 70.00 |
| Wire WD-1/TT on Reel DR-5. | 3. 30 | 82.00 |
| Wire WD-1/TT on Spool DR-8 | . 38 | 14. 00 |

## Section II. MOTORIZED AND HEAVY EQUIPMENT

## 9. Engineer Motorized and Heavy Equipment

The make, model, stock number, overall dimensions, weight in pounds, and cubage of the various items of engineer motorized and other heavy equipment, and the aircraft in which they are transportable, are given in table 10. Data are for working conditions.

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment

| Item | Make, model and stock No. | Dimension in inches |  |  | Weight in pounds | Cubic feet | Transjorting aircraft |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Length | Width | Height |  |  |  |  |
| Mixer, Bituminous: GD. 10, 30 | Barber Greene Model 840. 3895.221.1811. | 182. 0 | 88. 0 | 116 | 11,610 | 1, 075.1 | $\begin{array}{ll}\text { C-97 } & \mathrm{C}-1.30 \\ \mathrm{C}-119 & \end{array}$ |  |
| tons/hour. Unit 1 Mixer, |  |  |  |  |  |  |  |  |
| Bitum. Trl. Mtd. Comm. |  |  |  |  |  |  | C-123 | C-133 |
| 3895.221.1805. |  |  |  |  |  |  | C-124 |  |
| Drier, Aggregate: GD. 10-30 | Barber Greene Model 830. 3895-634-9178. | 146. 0 | 108. 0 | 217 | 13,325 | 1, 980.1 | C-119 | C-130 |
| tons/hour. Unit 2 Dry'r |  |  |  |  |  |  | C-123 |  |
| Aggreg. Trl. Mtd. Comp. |  |  |  |  |  |  | C-124 | C-133 |
| 3895.274.5035. | Barber Greene Model 839. 3895-634-8098. | 276. 0 | 118.0 | 132 | 18, 000 | 2, 487.0 | C-119 | C-130 |
|  |  |  |  |  |  |  | $\mathrm{C}-123$ |  |
|  |  |  |  |  |  |  | C-124 | $\mathrm{C}-133$ |
| Boat: Gas Powered 27/ft. Two | All makes and models.$1940-271.9726$ | 142.0 | 97.0 | $80 \ldots \ldots$ | (bow) 1, 150 | 518. 1 | C-97 |  |
| section. Aluminum. |  |  |  |  |  |  | C-119 | $\mathrm{C}-133$ |
|  |  | 189.0 | 97. 0 | 80-..... | (stern) 4,750 | 848.8 | C-123 |  |
|  |  |  |  |  | 5,900 |  | C-124 |  |
| Compressor: Air, Trailer Mtd. | Ingersoll-Rand Model IK-315. 4310.265.3158. | 153. 0 | 63. 0 | 89.----- | 8,500 | 496. 5 | C-97 | $\mathrm{C}-130$$\mathrm{C}-1.33$ |
| w/wheels. Pneumatic tires, |  |  |  |  |  |  | C-119 |  |
| DD. 315 CFM. 4310.203. |  |  |  |  |  |  | C-123 |  |
| 0569. |  |  |  |  |  |  | C-124 |  |
| Compressor: Air, Trailer Mtd. | $\begin{aligned} & \text { Le Roi Model 600D2 } \\ & \text { MOD. } 4310.265 .7929 . \end{aligned}$ | 156. 0 | 84.0 | 96, | 11, 000 | 728. 0 | C-97 | $\mathrm{C}-130$ |
| 4 wheels-Pneumatic tires, |  |  |  |  |  |  | C-119 |  |
| DD. 630 CFM. 4310.203.- |  |  |  |  |  |  | $\mathrm{C}-123$ | $\mathrm{C}-133$ |
| 0569. |  |  |  |  |  |  | C-124 |  |

Compressor: Air, Trailer Mtd. 4 wheels-Pneumatic tires, DD. 315 CFM. 4310.203.0569.

Compressor: Air, Trailer Mtd. 4 wheels-Pneumatic tires, DD. 600 CFM. 4310.203.0569.

Compressor: Air, Truck Mtd. GD 210 CFM. 4310.542.4408.

Compressor, Rotary: Air, Skid, Mtd. 125 CFM, 100 PSI. 4310.542.5783.

Crane: Shovel, Truck Mtd. GD, 20 ton, $3 / 4 \mathrm{Cu}$. Yd. 3810.554.4103.



| 6, 000 | 450. 0 | C-97 | C-130 |
| :---: | :---: | :---: | :---: |
|  |  | C-119 |  |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 10, 000 | 700.0 | C-97 | C-130 |
|  |  | C-119 |  |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 16, 300 | 1,569. 0 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 15,100 | 1,303. 0 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 27, 150 | 835.6 | C-124 | C-133 |
| 30, 050 | 1,944. 1 | C-19 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 53, 000 | 2, 660. 7 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 29, 370 | 1,944. 1 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 55, 300 | 2, 936. 0 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 31, 225 | 1,944. 1 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment-Continued

| Item | Make, model and stock No. | Dimenston in tuches |  |  | Weight $\ln$ pounds | Cubic feet | Transporting alreraft |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Length | Width | Height |  |  |  |  |
| Crane-Continued | Bucyrus Erie Model 22B. 3810.189.9692. CAB | 147.0 | 96.0 | 94 | 21, 090 | 767.7 | $\begin{aligned} & \mathrm{C}-119 \\ & \mathrm{C}-123 \\ & \mathrm{C}-124 \end{aligned}$ | $\mathrm{C}-130$ |
|  | Bucyrus Erie F.W.D. MUC., 6.by 6. Carrier. | 302. 0 | 103. 0 | 109 | 26,100 | 1, 944.1 | $\begin{aligned} & \mathrm{C}-119 \\ & \mathrm{C}-123 \\ & \mathrm{C}-124 \end{aligned}$ | $\begin{aligned} & \mathrm{C}-130 \\ & \mathrm{C}-133 \end{aligned}$ |
| Crane: Non-revolving, Tractor Oper. Wheeled, 40,000 Cap. 20 ft . Boom. 3810.234 .5118 . | Le Tourneau Model M- $\text { 20. } 3810.234 .5119 .$ | 330.0 | 115. 0 | 230 | 8,400 | 5, 051.2 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \\ & \mathrm{C}-123 \end{aligned}$ | C-130 C-133 |
| Crusher, Jaw: Rock, Airborne. 15 TPH Capacity. 3820.286. 9190. | Iowa Unit. 3820.030.1612 Iowa Unit. AB-1524-SP-15T. | 224.0 | 80.0 | 92 | 16, 000 | 954.0 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \\ & \mathrm{C}-123 \\ & \mathrm{C}-124 \end{aligned}$ | C-130 C-133 |
| Distributor: Bituminous Mat'l. Trailer Mounted. 1,250 Gal. 3895.194.5927. | Entyre Model MX, Style RE. 3895.194.5937. | 194.0 | 92. 0 | 102 | 11,500 | 1, 053.5 | $\begin{aligned} & \mathrm{C}-119 \\ & \mathrm{C}-123 \\ & \mathrm{C}-124 \end{aligned}$ | $\mathrm{C}-130$ $\mathrm{C}-133$ |
| Distributor: Bituminous Mat'l. | Entyre Model MX, Style RE. 3895.641.6025. <br> Rosco Model MDE. 3825.383.7133. <br> Tank Assem. $\qquad$ <br> Chassis_ $\qquad$ | 328. 0 | 96. 0 | 99 | 22,300 | 1, 804.0 | C-119 | $\mathrm{C}-130$ |
| Truck Mounted. 800 Gal. 3895.663.4680. |  |  |  |  |  |  | $\mathrm{C}-123$ $\mathrm{C}-124$ | C-133 |
| Distributor: Water. Truck <br> Mounted. 1,000 Gal. $3825 .-$ <br> 275.2622.   <br>    |  | 266. 0 | 97.0 | 105. | 19,820 | 1, 567.8 | C-119 | C-130 |
|  |  |  |  |  |  |  | C-123 |  |
|  |  | 140.0 | 97.0 | 82 |  | 644.4 | C-124 | C-133 |
|  |  | 260. 0 | 94.0 | 105 |  | 1, 485. 1 |  |  |
|  |  |  |  |  |  | 2, 129. 5 |  |  |

Gencrator Set: Portable, Dicsel. Skid Mounted, 15 KW., 127-220 Volt, 3 phase, 60 eycle or $230-400$ Volt, 3 phase, 50 cycle. 6115.235 .8681.
Generator Set: Portable, Diesel, Engine-Driven, Skid Mountcd, 30 KW., 127-220 Volt, 3 -phase, 60 eycle, or $230-400$ Volt, 3 phase, 50 eyele. 6116.635.9955.

Grader: Road, Motorized, Dicsel, 12 ft . Mold Board. 3805.238.5108.

Kettle: Asphalt, Repair, Trailer Mounted w/Motor Driven Hand Spray, 110 Gal. capacity. 3895.247 .7592.
Kéttle: Asphalt, Repair, Trailer Mounted w/Motor Driven Hand Spray, 165 Gal. capacity. 3895.247.7592.
Kettle: Asphalt, Skid Mounted, w/Gas Powered Circulating Pump, 750 Gal. capacity. 3895.292.0078.

Ready Power Model RD-6-A 12
6115.236.9995.

Buda Model
6DTG-317. 6115.242 .2295 .

Caterpillar Model 12. 3805.26 I .5826.

Austin-Western Model 99 H .
3805.261 .5825

Littleford Model
US-66.
3895.247.7591.

Litileford Model 84-HD-3. 3895.247.7594.

Rosco Model KO. 3895.252.1183.


| 3,455 | 77. 3 | C-97 | C-130 |
| :---: | :---: | :---: | :---: |
|  |  | C-119 |  |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 2,995 | 65.8 | C-97 | C-130 |
|  |  | $\mathrm{C}-119$ |  |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 23,320 | 1, 583.5 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 22,000 | 1,663. 8 | C-119 | C-130 |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 1,262 | 163. 7 | C-97 | C-130 |
|  |  | C-119 |  |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 1,500 | 317.7 | C-97 | C-130 |
|  |  | C-119 |  |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |
| 6,500 | 403.7 | C-97 | C-130 |
|  |  | C-119 |  |
|  |  | C-123 |  |
|  |  | C-124 | C-133 |

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment-Continued

| Item | Make, model and stock No. | Dimension In inches |  |  | Weight in pounds | Cuble feet | Transporting alreraft |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Length | width | Helght |  |  |  |  |
| Lubricator: $11 / 4$ ton, Trailer Mounted. | Grey Mfg. Co. No stock number. | 167. 0 | 84.0 | 88 | 5,700 | 714.4 | $\begin{array}{ll}\mathrm{C}-97 & \mathrm{C}-130 \\ \mathrm{C}-119 & \\ \mathrm{C}-123 & \end{array}$ |  |
|  |  |  |  |  |  |  | C-124 | C-133 |
| Mixer: Concrete, Gas Driven, Trailer Mounted, Side Discharge, 4 wheels, 14 cu. ft. 3895.286.1145. | Ransome Model 14 SU. 3895.264.4810. | 121. ${ }^{\circ}$ | 88. 0 | 120-.--- | 5,970 | 739. 4 | $\begin{array}{ll}\mathrm{C}-97 & \mathrm{C}-130 \\ \mathrm{C}-119 & \end{array}$ |  |
|  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  | C-124 | C-133 |
| Mixer: Concrete, Gas Driven, | Construction Mach. Co. Model 16S. 3895.255.4134. | 115. 0 | 98.0 | 127. | 5, 780 | 828. 3 | C-119 | C-130 |
| Air Cooled, End Discharge, |  |  |  |  |  |  | C-123 |  |
| Trailer Mounted, 4 Pneu- |  |  |  |  |  |  | C-124 | C-133 |
| matic Tired Wheels, $16 \mathrm{cu} . \mathrm{ft}$. 3895.238.5094. |  |  |  |  |  |  |  |  |
| Roller: Road, Towed Type, | Le Tourneau Model W-2. 3895.250 .6054 . | 175.0 | 113.0 | 58. | 6, 040 | 663.7 | $\begin{array}{ll}\mathrm{C}-97 & \mathrm{C}-130 \\ \mathrm{C}-119 & \\ \mathrm{C}-123 & \end{array}$ |  |
| Sheeps Foot, 2 Drums, in line. |  |  |  |  |  |  |  |  |  |
| 3895.263.0121. |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | C-124 | C-133 |
| Roller: Road, Towed Type, Wheeled, 13 Pneumatic Tires. 3895.227.1599. | William Bros. Model 67W. 3895.243.5442. | 174. 0 | 89.0 | 46 | 3,550 | 412. 2 | $\begin{aligned} & \mathrm{C}-119 \\ & \mathrm{C}-123 \end{aligned}$ |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | C-124 | C-133 |
| Roller, $71 / 2$ Ton: Road, Towed Type, Wheeled, 4 Pneumatic Tires. 3895.641.7761. | Grace Model Wltr. 3895.243.2678. | 288. 0 | 96. 0 | 92-..--- | 19,000 | 1,472. 0 | $\begin{array}{ll}\mathrm{C}-119 & \mathrm{C}-130 \\ \mathrm{C}-123 & \end{array}$ |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | C-124 | C-133 |
|  | William Bros. Model 450 Mod. 3895.223.8412 . | 298. 0 | 96. 0 | 92 | 14,800 | 1,523. 1 | C-119 | C-130 |
|  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  | C-124 | C-133 |

Roller: Road, Powered, 10 ton, Gasoline, 3 Wheel. 3959.223 . 8397.

Rooter: Road, Cable Operated, 3 Tooth.

Seraper: Road, Towed Type, Cable Operated, 8 cu. yd. 3805.197.8574.

Seraper: Road, Towed Type, Cable Operated, $12 \mathrm{cu} . \mathrm{yd}$ 3805.261.5849.

Scraper: Road, Towed Type, Cable Operated, 12 cu. yd. 3805.197.8582.

Shop Equipment: Contact Maintenance, Mobile Shop, Mtd. on $3 / 4$ ton M56 Ordnance Chassis. 4940-294-9518.
Shop Equipment: General Purpose, Truck.

Shop Equip.: Org. Repair, Heavy, semi trailer, Mounted. 4940-287-4894.

Galion Model "Chief". 3895.194.8555.

Le Tourneau Model H-3. 3895.234.2545.

Le Tourneau Model
LS. 3805.197 .857 .9 .
Le Tourneau Model LP. 3805.197.8584.

Le Tourneau Model FU. 3805.378.9807.

Body by: McCare Powers Auto Body Shop. No stock number.
Motorized. No speeifie make or model. 4940-294-9516.
Semi-Trailer. No specific make or model.



Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—Continued


Dolly---------------------------

Tank: Alphalt, Steel, Trailcr Mounted, w/Steam Coils, 1,500 gal. 2330.294.6509.
Tractor: Crawler, Diesel, 8,600$12,000 \mathrm{DBP}$, w/Bulldozer Tilt, Hydraulic Front Mtd., Winch, Towing, Reversible, rear, 1 Drum. 2410.260.3944.
Tractor, Crawler Type, Dicsel Driven, 12,000-1,700 Lbs. DBP, w/Bulldozer Tilt, Power Control Unit, Fr. Mtd., Winch Reversible, Rear Mtd., 1 Drum.
Tractor: Crawler Type, Diesel Driven, 17,000-24,000 Lbs. DBP, w/Angle Dozer, Power Control Unit, Front Mtd. Cable, Operating, 1 Drum \& Winch Reversible, Rear Mounted, 1 Drum.
Tractor: Crawler Type, Diesel Driven, 28,100-38,000 Lbs. DBP, w/Bulldozer, Tilting, Cable Oper, Power Control Unit, Cable Operating, Front Mtd., 1 Drum, Power Control Unit, Cable Operating, Rear Mounted, 2 Drums.


| 6,340 | 433.1 |  | $\mathrm{C}-133$ |
| ---: | ---: | ---: | ---: |
| 8,650 | 394.5 | $\mathrm{C}-124$ | $\mathrm{C}-130$ |
| 32,550 | $2,459.7$ |  | $\mathrm{C}-133$ |
| 10,130 | $1,463.0$ | $\mathrm{C}-119$ | $\mathrm{C}-130$ |
| 16,062 |  | $\mathrm{C}-123$ |  |

Table 10. Dimensions, Weights, and Air Transportahilily of Engineer Equipment—Continued

| Item | Make, model and stock No. | Dimension in inches |  |  | Weight in pounds | Cubic feet | Tramsporting aireraft |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Length | Width | Meight |  |  |  |
| Tractor: 4 Wheels, Rubber | $\begin{aligned} & \text { Caterpillar DW20M. } \\ & 2420.200 .1297 . \end{aligned}$ | 229. 5 | 112. 4 | Reducible to 114.5 . | 49, 020 | 1, 923.0 | C-119 |
| Tired, DED, 27,022-38,000 |  |  |  |  |  |  | C-123 |
| lbs. DBP, Power Control |  |  |  |  |  |  | C-124 |
| Unit, 2 Drums. 2420.200. |  |  |  |  |  |  | C-130 |
| 1297. |  |  |  |  |  |  | C-133 |
| Tractor: Wheeled, Rubber | $\begin{aligned} & \text { MRS } 190 . \\ & \quad 2420.287 .5250 . \end{aligned}$ | 194.0 | 100. 0 | Reducible to 96 . | 29, 000 | 1, 451.9 | $\mathrm{C}-119$ |
| Tired, Industrial, DED, |  |  |  |  |  |  | $\mathrm{C}-123$ |
| 20,025-27,000 lbs. DBP, |  |  |  |  |  |  | C-124 |
| Cable operated, Rear Mount- |  |  |  |  |  |  | C-130 |
| ed, 2 Drums, Weight Transfer |  |  |  |  |  |  | C-133 |
| Device. 2420.287.5256. |  |  |  |  |  |  |  |
| Tractor: Wheelcd, Rubber | $\begin{aligned} & \text { MRS 150. } \\ & 2420.517 .0675 . \end{aligned}$ | 194. 0 | 96.0 | 115.......-- | Unknown | Unknown | C-119 |
| Tired, Industrial, DED, |  |  |  |  |  |  | C-123 |
| 14,025-20,000 lbs. DBP. |  |  |  |  |  |  | C-124 |
| 2420.517.0675. |  |  |  |  |  |  | C-130 |
|  |  |  |  |  |  |  | C-133 |
| Tractor: Crawler Type 8,600- | $\begin{aligned} & \text { Allis-Chalmers Model } \\ & \text { HD-5G. } \\ & 2410.229 .9459 . \end{aligned}$ | 174.0 | 73.0 | 71.5-...-- | 16,540 | 525. 6 | C-97 C-130 |
| 12,000 lbs. DBP, w/Loader |  |  |  |  |  |  | C-130 |
| Hydraulic Operated, Front |  |  |  |  |  |  | C-123 |
| Dump, $3 / 4$ cu. yd. Bucket. |  |  |  |  |  |  | C-124 $\quad$ C-133 |
| Trailer: 4 whcel, Tandem, 4 | All makes and models. 2330.377.0389. | 335. 0 | 98. 0 | 60.-.-.-.--- | 11, 750 | 1,139.9 | C-119 $\quad$ C-130 |
| Double Tire, Flat Bed, for |  |  |  |  |  |  | $\mathrm{C}-123$ |
| Crane Shovcl Attachment, 10 ton. |  |  |  |  |  |  | C-124 C-133 |
| Trailcr: Full Low Bed, 8 ton ${ }^{\text {- }}$ | All makes and models.$2330.273 .4421$ | 287.0 | 103.0 | 57--------- | 9, 680 | 975. 1 | $\begin{array}{ll} C-119 & \mathrm{C}-130 \\ \mathrm{C}-123 & \end{array}$ |
|  |  |  |  |  |  |  | C-124 C-133 |

Trailer: Dump, 7-8 cu. yd., For Tractor, Air Transportable, Wheel Type, 7,800 to 14,000 Ib., DBP, w/Weight Transfer Device.
Tractor, Saw, Power Unit, Wheelbarrow type, G.D. 3750.275.000.

Spreader: Aggregate, Towed, Traction Powered, 8 ft . width.

Tank: Water, Steel, SemiTrailer, Mounted, 1,500 gal. 2330.271.9947.

Pump: Water, Trailer Mounted w/Distributor Attachments. 3825.263.2975.

Pump: Water, Centrifugal, G.D., Trailer Mtd., 4 in. discharge, 4 in. suction, 500 GPM @ 20 ft . head, Normal discharge. 4320.289.3699.
Truck: Bolster Body, 21/2 ton, 6 by 6 with Front Mtd. Winch.

Water Purification Equipment: Diatomite \#3, Set \#3, Portable, 35 GPM.

| $\begin{aligned} & \text { M-R-S Model } 75 \\ & \text { AGW. } \\ & 2805.227 .0482 . \end{aligned}$ | 318. 0 | 96. 0 | 90----------1 | 10, 400 | 1,590.0 | $\begin{aligned} & \mathrm{C}-119 \\ & \mathrm{C}-123 \\ & \mathrm{C}-124 \end{aligned}$ | $\mathrm{C}-130$ $\mathrm{C}-133$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Little Giant Model $\begin{aligned} & 22-4 . \\ & 3750.275 .000 \end{aligned}$ | 133. 0 | 38. 0 | 36--------- | 1, 080 | 105. 3 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \\ & \mathrm{C}-123 \end{aligned}$ | C-130 |
| Good Roads Machinery Co. Model 8. 3895.223.8210. |  |  |  |  |  | C-124 | C-133 |
|  | 107. 0 | 45. 0 | 37--------- | 1, 550 | 103. 1 | C-97 <br> C-119 <br> C-123 | C-130 |
|  |  |  |  |  |  | C-124 | C-133 |
| Columbian SteelTank Co.2330.368.2818. | 220. 0 | 96. 0 | 90 | 7, 000 | 1, 100. 0 | C-119 | C-130 |
|  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  | C-124 | C-133 |
| Rosco Model MAE. 3825.269.2976. | 180. 0 | 78. 0 | 73- | 2, 200 | 593.1 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \end{aligned}$ | C-130 |
|  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  | C-124 | C-133 |
| Carver Model 4822. 4320.289.3699. | 48.0 | 37.0 | 51--------- | 800 | 52. 4 | $\mathrm{C}-97$ | C-130 |
|  |  |  |  |  |  | C-119 |  |
|  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  | C-124 | $\mathrm{C}-133$ |
| GMC Model CCK W353. 2320.287.4249. | 268. 0 | 87. 0 | 96--------- | 11, 400 | 1, 295.3 | C-97 | C-130 |
|  |  |  |  |  |  | C-119 |  |
|  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  | C-124 | C-133 |
| 4610.190.0300_-.-.--- |  |  |  | 3, 800 |  | (1) |  |
|  |  |  |  | (uncrated) |  |  |  |
|  |  |  |  | 5,200 |  |  |  |
|  |  |  |  | (for export) |  |  |  |

[^2]Table 10. Dimensions, Weights, and Air Transportalility of Engineer Equipment-Continued

| Item | Typical truckloads |  |  | Dimension in inches |  |  | Weight in pounds | Cubte feet | Transporting alreraft |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Required | LD | Load name | Length | Width | Heiglit |  |  |  |  |
| Bridge: Floating M-4. 5420-267-0011. | 2 | C | Shallow Water Accessorics. | 178 | 78 | 49 | 4,505 | 393.7 | $\begin{array}{ll}\mathrm{C}-119 & \mathrm{C}-130 \\ \mathrm{C}-123 & \end{array}$ |  |
|  | 28 | D | Pontons-------------- | 367 | 87 | 58 | 10,359 | 1,071.7 | $\mathrm{C}-119$ $\mathrm{C}-123$ | C-130 |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 2 | E | Approach Accessories . - | 180 | 79 | 62 | 7, 850 | 510. 2 | C-119 | C-130 |
|  |  |  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 4 | F | Abutment Equipment.- | 180 | 79 | 46 | 8, 007 | 378. 5 | C-119 | C-130 |
|  |  |  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 12 | C | Tresties-------------- | 180 | 78 | 55 | 11, 954 | 446. 9 | $\begin{array}{ll}\mathrm{C}-119 & \mathrm{C}-130 \\ \mathrm{C}-123 & \end{array}$ |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 4 | H | Ferry Liquipment.-...-- | 180 | 78 | 35 | 5,346 | 284. 4 | $\begin{array}{ll}\mathrm{C}-119 & \mathrm{C}-130 \\ \mathrm{C}-123 & \end{array}$ |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 2 | I | Spare Components...-. | 180 | 78 | 74 | 14, 121 | 601. 3 | C-119 | $\mathrm{C}-130$ |
|  |  |  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 6 | J | Floats and Saddles . . - | 144 | 78 | 51 | 7,512 | 331.5 | C-119 | C-130 |
|  |  |  |  |  |  |  |  |  | C-123 | - |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |

Bridge: Floating, Pneumatic Float, Class 60, Steel Superstructure. 5420-2670012.

Bridge: Fixed Steel Panel, Bailey Type M-2. 5420-530-3784. Erection Set. 5420-530-3785.

| 40 | A | Floating Bay ........-- | 224 | 98 | 68 | 16,303 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 2 | B | Ramp Load A------- | 224 | 98 | 66 | 17, 074 |
| 2 | C | Ramp Load B------- | 195 | 98 | 65 | 16, 287 |
| 2 | D | Anchorage Load.......- | 176 | 98 | 37 | 10, 832 |
| 2 | F | Trestle_ | 272 | 98 | 42 | 15, 817 |
| 4 | F | Miscellaneous-.------- | 176 | 98 | 48 | 1, 669 |
| 2 | \#1 | Accessory - | 201 | 80 | 32 | 6, 024 |
| 4 | \#2 | Ramp---------------- | 167 | 80 | 24 | 4,939 |
| 7 | \#3 | Decking-..---.-.-.-.-- | 167 | 80 | 26 | 6,645 |


| 863. 9 | C-119 | C-130 |
| :---: | :---: | :---: |
|  | $\mathrm{C}-123$ |  |
|  | C-124 | C-133 |
| 383. 1 | C-119 | C-130 |
|  | C-123 |  |
|  | C-124 | $\mathrm{C}-133$ |
| 718. 3 | C-119 | C-130 |
|  | $\mathrm{C}-123$ |  |
|  | C-124 | C-133 |
| 469. 1 | C-119 | C-130 |
|  | C-123 |  |
|  | C-124 | C-133 |
| 647. 9 | C-119 | C-130 |
|  | C-123 |  |
|  | C-124 | C-133 |
| 479. 1 | C-119 | C-130 |
|  | C-123 |  |
|  | C-124 | C-133 |
| 297.8 | C-97 | C-130 |
|  | C-119 |  |
|  | C-123 |  |
|  | C-124 | C-133 |
| 185. 6 | C-97 | C-130 |
|  | C-119 |  |
|  | C-123 |  |
|  | C-124 | C-133 |
| 185. 6 | C-97 | C-130 |
|  | C-119 |  |
|  | C-123 |  |
|  | C-124 | -13 |

Table 10. Dimensions, Weights, and Air Transportability of Engineer Eguipment-Continued

| Item | Typlcal truckloads |  |  | Dimension in inches |  |  | Welght in pounds | Cuble feet | Transporting |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Required | 1,D | Load name | Length | Width | Height |  |  |  |  |
|  | 14 | \#4 | Panel.-------- | 124 | 75 | 62 | 5,791 | 333. 7 | $\begin{array}{ll}\text { C-97 } & \mathrm{C}-130 \\ \mathrm{C}-119 & \end{array}$ |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  | . $\mathrm{C}-123$ |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 5 | \#5 | Transom | 240 | 80 | 16 | 5,336 | 177.8 | C-97 | C-130 |
|  |  |  |  |  | . |  |  |  | C-119 |  |
|  |  |  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 2 | \#6 | Footwalk | 120 | 80 | 33 | 3, 058 | 183. 3 | C-97 | C-130 |
|  | 2 | \# | Footwalk. |  |  |  |  |  | C-119 |  |
|  |  |  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |
|  | 2 | \#7 | Grillage - | 163 | 80 | 12 | 3, 744 | 90.6 | C-97 | C-130 |
|  | 2 | \# | Grillage-- |  |  |  |  |  | C-119 |  |
|  |  |  |  |  |  |  |  |  | C-123 |  |
|  |  |  |  |  |  |  |  |  | C-124 | C-133 |

Table 10. Dimensions, Weights, and Air Transportability of Engineer EquipmentContinued

| Item | Length (inches) | Width (inches) | Height (inches) | Welght (pounds) | Transporting aircralt |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Tractor, Crawler, Diesel, Airborne D6-S. 2410-240-2738. | 166 | 88 | 80 | 15,500 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \\ & \mathrm{C}-123 \end{aligned}$ | $\mathrm{C}-130$ $\mathrm{C}-133$ |
| Traxcavator, Cat. Model 933..- | 166 | 70 | 76 | 15, 400 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \\ & \mathrm{C}-123 \end{aligned}$ | C-130 |
|  |  |  |  |  | C-124 | C-133 |
| Bucket, Clamshell, 3.4 yd. 3815-272-8674. | 70 | 65 | 34 | 2, 400 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \\ & \mathrm{C}-123 \end{aligned}$ | C-130 |
|  |  |  |  |  | C-124 | C-133 |
| Bucket, Dragline, 3.4 yd. 3815-186-3571. | 90 | 40 | 60 | 2, 100 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \end{aligned}$ | C-130 |
|  |  |  |  |  | C-123 |  |
|  |  |  |  |  | C-124 | C-133 |
| ```Grader, Road, Air Transport- able, Cat. 212. 3805-223- 9029.``` | 264 | 79 | 101 | 14,220 | $\begin{aligned} & \mathrm{C}-97 \\ & \mathrm{C}-119 \end{aligned}$ | C-130 |
|  |  |  |  |  | $\mathrm{C}-123$ |  |
|  |  |  |  |  | C-124 | C-133 |
| Roller, Sheepsfoot, Airborne, Model TRO-112. 3895-3519805. | 175389 | 115 | 58 | 6, 040 | C-97 | C-130 |
|  |  |  |  |  | C-119 |  |
|  |  |  |  |  | C-123 |  |
|  |  |  |  |  | C-124 | C-133 |
| Scraper, Road, Towed, Ty., 12 cu. yd., Le Tourneau Model LPO. 3805-351-9542. | 389 | 125 | 133 | 20, 175 | C-124 | C-133 |
| Tank, Water, Skid. 5430-2566601. | 96 | 52 | 48 | 760 | C-97 | C-130 |
|  |  |  |  |  | C-119 |  |
|  |  |  |  |  | C-123 |  |
|  |  |  |  |  | C-124 | C-133 |

## 10. Ordnance Vehicles

The overall dimensions, volumes in measurement tons, and net weights of certain ordnance vehicles issued to engineer units are given in table 11.

Table 11. Ordnance Vehicles Issued to Engineer Troop Units

| Vehicle | Dimensions (inches) |  |  | Measurement tons | Net weight, pounds |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Lengtb | Width | Helght |  |  |
| Trailer, cargo, 1/4-ton, 2-wh | 1081/2 | 561/4 | 42 | 3. 7 | 565 |
| Trailer, amphibious cargo, $1 / 4$-ton, 2-wheel | 1081/2 | 56 | 40 | 2. 9 | 550 |
| Trailer, cargo, 3/4-ton, 2-wheel (M101) | 1433/4 | 731⁄2 | 83 | 4. 4 | 1,340 |
| Trailer, cargo, $11 / 2$-ton, 2 -wheel (M104) | 1651/2 | 83 | $1991 / 8$ | 7. 1 | 2, 400 |
| Trailer, water-tank, $1 \frac{1}{2}$-ton, 2 wheel (M106) | 1665/8 | ${ }^{2} 93$ | 793/4 | 17. 5 | 2, 280 |
| Truck, utility, $1 / 4$-ton, 4 by 4 (M38, Willys) $\qquad$ | 133 | 62 | ${ }^{3} 74$ | 6. 7 | 2, 625 |
| Truck, pickup, $1 / 2$-ton, 4 by 2 (Chevrolet) | 197 | 75 | 76 | 16. 3 | 3, 330 |
| Truck, cargo, $3 / 4$-ton, 4 by 4 (M37, Dodge) $\qquad$ | 1893/8 | 731/2 | $4891 / 2$ | 12. 6 | 5, 917 |
| Truck, command, $3 / 4$-ton, 4 by 4 (M42) $\qquad$ | 1843/4 | 731/2 | $893 / 4$ | 17. 4 | 6, 050 |
| Truck, ambulance, $3 / 4$-ton, 4 by 4 (M43) | 198\%/8 | 731/2 | 917/8 | 19.8 | 7, 150 |
| Truck, stake and platform, $11 / 2$-ton, 4 by 2 (Chevrolet) $\qquad$ | 265 | $87^{1 / 2}$ | 88 | 29.6 | 5, 675 |
| Truck, cargo, $2 \not 12$-ton, 6 by 6 LWB <br> (GMC) | 2561/4 | 88 | 93 | 30. 4 | 10, 550 |
| Truck, cargo, $2 \nmid 2$-ton, 6 by 6, LWB, WW (GMC) | 2701/8 | 88 | 93 | 32. 0 | 11,250 |
| Truck, dump, $2 \frac{1}{2}$-ton, 6 by 6 <br> (M47) | 2351/8 | 85 | 104 | 30.0 | 13, 540 |
| Truck, gasoline tank, $2 \frac{1}{2}$-ton, 6 by 6, 750-gal (GMC) | 2531⁄2 | 91 | ${ }^{5} 93$ | 31. 1 | 10,750 |
| Truck, gasoline-tank, $21 / 2$-ton, 6 by 4, 1,350-gal | 288 | 92 | 95 | 36. 5 | 11, 100 |
| Truck, shop van, $2 \frac{1}{2}$-ton, 6 by 6 (M535) | 2551/2 | 96 | ${ }^{6} 118$ | 33. 5 | 10, 100 |
| Truck, stake and platform, 21/2ton, 4 by 2 (International Harvester) $\qquad$ | 276\%\%8 | 921/4 | 911/4 | 33.8 | 7,110 |
| Truck, water-tank, $21 / 2$-ton, 6 by 6 , 700-gal (GMC) | 2531⁄2 | 90 | 95 | 31.5 | 11,913 |
| Truck, cargo, 5 -ton, 6 by 6, LWB, WW (M41) | 3093/4 | 96 | ${ }^{7} 1181 / 8$ | 47.8 | 19,835 |
| Truck, dump, 5-ton, 6 by 6 (M51) -- | 2661/8 | 97 | ${ }^{8} 110 \frac{5}{8}$ | 41.5 | 21,981 | See footnotes at end of table.

Table 11. Ordnance Vehicles Issued to Engineer Troop Units—Continued

| Vehicle | Dimensions (inches) |  |  | Measurement tons | Net welght, jounds |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Length | width | Height |  |  |
| Truck, dump, 5 -ton, 6 by 6, ww <br> (M51) | 2815/8 | 97 | ${ }^{8} 1105 \%$ | 43. 9 | 22,664 |
| Truck, medium wrecker, 5-ton, 6 by 6 | 3093/4 | 97 | 1021/2 | 61.7 | 33, 675 |
| Truck, tractor, 5 -ton, 6 by 6 , SWB, WW (M52) | 273 | 97 | ${ }^{8} 102$ | 39.5 | 18,996 |
| Truck, tractor, 12 -ton, 6 by 6 (H26) | 306 | 1301/2 | 123 | 74. 0 | 48, 895 |
| Vehicle, armored, tracked....... | 214 | 113 | 771/2 | 28.2 | 35, 500 |

${ }^{1}$ Can be collapsed to 58 inches.
${ }^{2}$ Retractable to 83 inches.
${ }^{3}$ Reducible to 55 inches.
${ }^{4}$ Reducible to 63142 inches.

* Reducible to $813 / 2$ inches.


## 11. Vehicles Upon Which Smaller Vehicles Can Be Loaded.

Table 12. Loading Vehicles on Vehicles

| Small vehicles | 21/2-ton 6 by 6 cargo (LWB) | $\begin{aligned} & 21 / 2 \text {-ton } 6 \mathrm{by}^{6}{ }^{6} \\ & \text { cargo (SWB } \end{aligned}$ | $\begin{aligned} & 1 \frac{1}{2} \text {-ton } 4 \text { by } 4 \\ & 15 \text { foot cargo } \end{aligned}$ | 11/2-ton 4 by 4 cargo truck |
| :---: | :---: | :---: | :---: | :---: |
| 1/4-ton 4 by 4 truck_ | Yes | Possible ${ }^{1}$ | Yes | Possible. ${ }^{2}$ |
| 1/4-ton 2-wheel cargo trailer. | Yes. | Yes-...-.-. | Yes. | Yes. |
| 1-ton 2-wheel cargo trailer. | Yes. | Possible ${ }^{3}$ - -- | Possible 4--- | Possible. ${ }^{5}$ |
| 1-ton 2-wheel 250-gallon tank trailer. | Yes | Possible ${ }^{6}$. - | Possible ${ }^{7}$. . | Possible. ${ }^{7}$ |

[^3]12. Fuels, Lubricants, Hydraulic Fluids, and Antifreeze for Engineer Equipment.
$a$. Fuels, lubricants, and hydraulic fluids are issued for enginecr equipment, depending on ambient conditions, as indicated in table 13.
b. Two types of antifrecze are issued. Ethylene glycol is normally issued when temperatures from $32^{\circ} \mathrm{F}$. to $-25^{\circ} \mathrm{F}$. are anticipated. This is mixed with the engine coolant in varying proportions. Arctic antifreeze is normally issued for anticipatcd temperatures under $-25^{\circ} \mathrm{F}$. Arctic antifreeze is premixed and does not permit addition of water.
c. In addition to these two antifreeze materials it is common practice to add denatured alcohol to engine and heater fuel tanks when subfreezing temperatures are encountered. It is normally added in a ratio of one quart of alcohol to $30-50$ gallons of gasoline.
d. Special priming devices and fluids are required to assist in starting diesel engines at extremely low temperatures. The Chevron Model Discharger (SNL number 78-3200-600-400) and the priming fluid capsules (78-6827.500.500) are provided for this purpose.
$e$. In addition to the above it is necessary to provide special winterization to standard equipment for opcrations in extremely low temperatures. Items such as special fan belts, hose, engine preheaters, and personnel heaters are required.

Table 13. Stock Military Fuels, Lubricants, Hydraulic Fluids, and Antifreezes for Engineer Equipment

| Product | Federal stoek No. | Container size | Applieable temperature range |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Above $32^{\circ} \mathrm{F}$. |  | $32^{\circ} \mathrm{F}$. to $-25^{\circ} \mathrm{F}$. |  | $-25^{\circ} \mathrm{F}$. to $-65^{\circ} \mathrm{F}$. |  |
|  |  |  | Specification | Symbol | Specification | Symbol | Specifleation | Symbol |
| Fuel oil, diesel, regular.-- | 9140-286-5296 | 55 gal . | VV-F-800 (Federal)-- | DF-2 |  |  |  |  |
| Fuel oil, diesel, winter grade.-------- | 9140-286-5288 | 55 gal . |  |  | VV-F-800 (Federal) | DF-1 |  |  |
| Fuel oil, diescl, aretie grade. | 9140-286-5284 | 55 gal . |  |  | VV-F-800 (Federal)..... | DF-A | VV-F-800 (Federal) | DF-A |
| Gasoline, auto, combat (general)....-- | 9130-221-0680 | 55 gal . | MIL-G-3096, type I. | 91A |  | DF-A | VV-F-800 (Federal)----- | DF-A |
| Gasoline, auto, combat (low temp).-. | 9130-221-0685 | 55 gal . |  |  | MIL-G-3056A, type II.- | 91C | MILL-G-3056A, type II. | 01C |
| Lubr. oil, int. comb. eng------------- | 9150-265-9435 | $5 \mathrm{gal} . .$. | MIL-L-2104A | OE30 | MIL ${ }^{\text {a }}$ - | 010 | MIL-G-3050A, type II.- | OIC |
| Lubr. oil, int. comb. eng., Subzero...- | 9150-242-7603 | 5 gal . |  |  | MIL-O-10295A | OES | MIL-O-10295A | OES |
| Lubr. oil, gear, grade 90-----------...- | 9150-240-2251 | 15 gal . | MIL-L-2105 | G O-90 |  |  | M1L-0-10205 | OES |
| Lubr. oil, gear, grade 75-------------- | 9150-240-2243 | 15 gal . |  |  | MII-L-2105. | GO-75 |  |  |
| Lubr. oil, gear, subzero ---------- | 9150-257-5441 | 15 gal. |  |  | MIL-L-10324 (ORD).-- | GOS | MIL-L 10324 (ORD) .-- | GOS |
| Greases: <br> Aircraft and instrument (for sealed bearings). | 9150-261-8298 | 1 lb .---- | MIL-G-3278 | GL | MIL-G-3278..------------ | GL | MIL-G-3278------------- | GL |
| Automotive and artillery (for chassis clements). | 9150-190-0907 | 35 lb - --- | MIL-G-I0924, A md 3-.- | GAA | MIL-G-10924, Amd 3.-- | GAA | MIL-G-10924, Amd 3--- | GAA |
| Automotive (water pump)-------- | 9150-235-5503 | 1 lb....- | $\begin{aligned} & \text { VV-G-632, type A, } \\ & \text { grade } 4 \text { (Federal). } \end{aligned}$ | WP | $\begin{aligned} & \text { VV-G-632, type A, } \\ & \text { grade } 4 \text { (Fedcral). } \end{aligned}$ | WP | $\begin{aligned} & \text { VV-G-632, type A, } \\ & \text { grade } 4 \text { (Federal). } \end{aligned}$ | WP |
| Hydraulie fluld, non-petr. (brake system). | 9150-231-9071 | $1 \mathrm{gal} . . .-$ | VV-F-451a (Federal).-.- | HB | VV-F-451a (Federal)...- | HB |  |  |
| Hydraulic fluld, non-petr., aretie type (brake system). | 9150-252-6375 | 1 gal -.-- |  |  |  |  | M IL-H-13910.....-.----- | HBA |
| Hydraulle fluid, petr. base-.-.-------- | 9150-223-4134 | $1 \mathrm{gal} . .-$ | MIL-O-5606. | OHA | MIL-0-5606.-.-......... | OHA | MIL-O-5606. | OHA |
| Lubr. oil, instrument-------------.-- | 9150-223-4129 | 1 qt ---.. | MIL-L-6085. | OAI | MIL-L-6085 ------------ | OAI | MIL L-6085.------------- | OAI |
| Antlfreeze, ethylene-glycol type------ | 6850-243-1992 | 55 gal -- |  |  | O- E-771a (Federal)..... |  |  |  |
| Antifrecze, aretie type---------------- | 6850-243-1991 | 55 gal . |  |  | MIL-C-11755-.--------- | CA-A | MIL $\mathrm{C}-11755$ | CA-A |
| Alcohol, denatured, gr III.. |  | $1 \mathrm{gal}^{\text {. }}$ - |  |  | O-A-396 (Federal) -...-. |  | O-A-396 (Federal) .-...- |  |

## 13. Fuel and Lubricant Consumption

Those vehicles or pieces of equipment marked with an asterisk show petroleum consumption based on "gallons per hour" (GPH); those vehicles or pieces of equipment marked with 2 asterisks show the petroleum consumption rate based on the movement of a unit for 50 miles. The factors influencing petroleum consumption are as follows:
a. Cross-country movement is estimated at two and one-half times the consumption over roads.
b. For arctic winter operations, increase all basic amounts by 25 percent.
c. To cover such items as spillage, evaporation, and small combat losses, an additional 10 percent of the total consumption figure should be included in the estimation.
d. An experienced vehicle or equipment operator will, as a general rule, use less petroleum products than an inexperienced person.
$e$. The newness and condition of the vehicles and equipment will have a bearing on the estimated amounts of petroleum products required, and should be considered.
$f$. The movement of vehicles and equipment within bivouac areas and on reconnaissance, the warming up of engines, and abnormal periods of low-gear operation must be considered when estimating petroleum requirements.
g. Additional daily requirements exist for administrative vehicles, gasoline-powered equipment, and maintenance and testing of engines.

Table 14. Fuel and Lubricant Consumption Rates of Engineer and Ordnance Equipment

| Item | Oasoline | Diesel | $\mathrm{c}_{\text {Oallons }}^{\substack{\text { OE }}}$ | Oallons $0090$ | Pounds GAA |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Auger, earth, trk, mtd.* | 2. 5 |  | . 03 | . 03 | 06 |
| Cleaning unit, steam, shop, whl. mtd., oil burner.* |  | 1 |  |  |  |
| Compressor, air, 3 stages 15 CFM, GED.* $\qquad$ | 6 |  | . 02 |  |  |
| Compressor, air, 210 CFM, trk. mtd.* $\qquad$ | 5 |  | . 04 | . 03 | 05 |
| Compressor, air, piston and rotary types, 315 CFM.* |  | 4 | 1 |  | 04 |
| Conveyor, skd. mtd. 24 by 50 GED.* $\qquad$ | 2 |  | . 04 | . 09 | 06 |
| Crane, $3 / 4 \mathrm{cu} . \mathrm{yd} .$, trk. mtd.*.-.- | 4. 3 |  | . 06 | . 03 | 05 |
| Crane, 20 ton, non-revolving.*-- |  |  |  |  | 03 |
| Crane, 2 cu. yd., CLR.*- | 5. 7 |  | . 09 | . 09 | 1 |
| Crushing Plant, 3 unit, 50 ton per hour.* $\qquad$ | 2 | 5 | 5. 8 | . 35 | 25 |
| Ditching machine, ladder type, 8 ft . depth.* | 5 |  | . 06 | . 09 | . 1 |

Table 14. Fuel and Lubricant Consumption Rates of Engineer and Ordnance Equipment-Continued

| Item | Gasollne | Dlesel | $\begin{gathered} \text { Gallons } \\ O E \end{gathered}$ | $\begin{aligned} & \text { Gallons } \\ & \text { OO90 } \end{aligned}$ | Pounds <br> GAA |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Distributor, bit., trk. mtd. 800 gal. cap.* | 4. 1 |  | . 04 | . 03 | 05 |
| Distributor, water, trk. mtd., 1000 gal.* $\qquad$ | 4. 1 |  | . 04 | . 03 |  |
| Dolly, 4 wheel for 20 ton semi.*-- |  |  |  |  | 03 |
| Electric lighting equipment, set \#4, 5 KW.* $\qquad$ | 3. 5 |  |  | . 03 |  |
| Electric lighting equipment, set \#5, trk. mtd., 15 KW.* | 3 |  | . 05 |  |  |
| Flood light equipment, set \#2, GED.* $\qquad$ | 3. 5 |  | . 03 |  |  |
| Grader, road motorized.* |  | 4 | . 06 | . 03 | 0 |
| Heater, asphalt, tlr. mtd.*----- | 6 | 2. 5 | . 02 |  | 02 |
| Kettle, asphalt, tlr. mtd., 165 gal.* $\qquad$ | . 6 | 2 | . 02 |  | 03 |
| Loader bucket.* | 8. 75 | 5 | . 04 | . 03 | 06 |
| Lubricator, tlr. mtd. | 1 |  | . 02 |  | 01 |
| Mixer, concrete, tlr. mtd. 16 cu. ft.* $\qquad$ | 2 |  | 03 |  | 03 |
| Mixer, rotary-tiller.* | 2. 3 | 3. 8 | . 09 | . 06 | 06 |
| Power unit, \#162.* | 6 |  | . 01 |  |  |
| Pump, asphalt, tlr. mtd.* | 2 |  | . 03 |  | 03 |
| Pump, diaphragm, push cart mtd.* | . 6 |  | . 02 |  |  |
| Pump, centrifugal for gas, $3^{\prime \prime}$ by 240 GPM @ 60 ft . head.* $\qquad$ | . 8 |  | . 03 |  |  |
| Quarry set \#1, wagon drills.* |  |  | . 03 |  | 0 |
| Roller, road, 5-8 ton.* | 2 |  | . 05 | 02 | 03 |
| Roller, road, 3 wheel, 10 ton.*-- | 2.5 |  | 03 | 03 | 03 |
| Roller, road, towed type, 50 ton.* |  |  |  |  | 03 |
| Roller, road, towed type, 13 wheel.* |  |  |  |  | 03 |
| Roller, road, towed type, sheepfoot.* $\qquad$ |  |  |  |  | 03 |
| Rooter, 3 tooth, H-3.* |  |  |  |  | 03 |
| Scraper, towed type, 8 cu. yd.* |  |  |  |  | 04 |
| Scraper, towed type, 12 cu. yd.* $\qquad$ |  |  |  |  | 05 |
| Scraper, towed type, 18 cu. yd.* $\qquad$ |  |  |  |  | 06 |
| Shop equipment, motorized GP.* | 1. 6 |  | 02 | . 03 | 05 |
| Shop equipment, motorized, heavy machine.* | 1. 6 |  | . 02 | . 03 | . 05 |
| Spreader, aggregate, towed type.* |  |  | 03 |  |  |
| Sweeper, 2-way, sweeping.* |  |  | . 03 |  | . 03 |
| Tool set \#3, emergency shop, $1 \not 1 / 2 \mathrm{KW}$ gen., GED.* | . 6 |  | 02 |  |  |

Table 14. Fuel and Lubricant Consumption Rates of Engineer and Ordnance Equipment-Continued

| 1 tem | Gasoline | Diesel | $\underset{\mathrm{OE}}{\text { Gallons }}$ | $\begin{gathered} \text { Gallon } \\ \text { OO90 } \end{gathered}$ | Pounds GAA |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Tractor, saw, wheelbarrow type.* | 1 |  | . 02 | . 02 | 04 |
| Tractor, wheel type, 3,000 to 3,700 DBP.* $\qquad$ | 3 |  | . 03 | . 03 | 05 |
| Tractor, wheel type, 20,025 to 27,000 DBP.* |  | 6. 3 | . 2 | . 06 | . 04 |
| Tractor, D-6.*----------------1 | 2 | 6 | . 1 | . 07 | . 05 |
| Tractor, D-7.* | 2 | 6 | . 1 | . 07 | . 05 |
| Tractor, D-8.* | 2 | 6 | . 1 | . 07 | 05 |
| Truck, utility, $1 / 4$ ton, 4 by $4 . * *$ - | 3 |  | . 1 |  | 2 |
| Truck, $3 / 4$ ton, 4 by 4.**---.--- | 6 |  | . 1 | - | . 3 |
| Truck, $11 / 2$ ton, 4 by 4.**. $\ldots$. | 7 |  | . 2 |  | . 5 |
| Truck, $11 / 2$ ton, 6 by 6.**-.-..- | 7 |  | . 2 |  | . 4 |
| Truck, $21 / 2$ ton, 6 by 6.**---.--- | 9 |  | . 2 |  | 6 |
| Truck, 4 ton, 6 by 6.** $\ldots \ldots$ | 17 |  | . 3 |  | 1 |
| Truck, wrecker, 4 ton, 6 by 6.**_ | 17 |  | . 3 |  | 1 |
| Truck, dump, 5 ton.**.----..- | 20 |  | 1. 3 | . 8 | 1. 3 |
| Truck, 5 ton, 6 by 6.**_-.-.-- | 17 |  | . 4 | - - - | . 9 |
| Truck, med. wrecker, 5 ton, 6 by 6.** $\qquad$ | 19 | ------- | . 4 | -- | . 5 |
| Truck, prime mover, 6 ton, 6 by 6.** $\qquad$ | 25 |  | . 5 |  | . 9 |
| Truck, hvy wrecker, 6 ton, 6 by 6.** $\qquad$ | 20 |  | . 5 |  | . 9 |
| Truck, prime mover, $71 / 2$ ton, 6 by 6.** | 20 |  | 5 |  | 9 |
|  | 34 |  | . 4 |  | . 7 |
| Truck, tractor, 5-6 ton (10-ton semitrailer).** | 17 |  | . 4 |  | . 6 |
| Truck, tractor, 12 ton.**.-.-. - | 50 |  | . 9 | . 3 | 1. 3 |
| Water, purification set \#3, GED.** $\qquad$ | 5 |  |  | . 6 |  |

## 14. Identification of Engineer Equipment Repair Parts

Manufacturers frequently stamp individual parts with a part number which furnishes a hint as to the part's identity. However, many parts bear stamped or casting numbers which are not the manufacturer's part number, and numerous manufacturers have parts which bear no number. Some manufacturers who use a parts-numbering system and a summary of their systems are showy in table 15.
$a$. The supply manuals in the $5-3$-series contain identification and cross reference information for all Engineer repair parts which arc assigned Federal Stock Numbers and are stocked in the CONUS Depot system.
$b$. Supply Manuals $5-3-1-1$ through $5-3-1-6$ contain the manufacturer's part and/or drawing number, the item noun, corresponding Federal Stock Number and former Engineer Stock number for the
item. The manufacturer's part and/or drawing numbers, which are arranged in alphabetical-numerical sequence in this scrics of manuals, will sometimes correspond with the manufacturcr's stamped or casting number found on the part. This information would provide some assistance in the identification of Enginecr rcpair parts where only the stamped or casting number is available.

Table 15. Engineer Equipment Repair Parts Identification

| Manufacturer | Parts-numbering system |
| :---: | :---: |
| Allis-Chalmers Manufacturing Company (power units). | Six-digit numbers. Parts manufactured on subcontracts bear a 2 - to 4 -digit number, often that of the contractor, prefixed by the letter U. |
| Allis-Chalmers Manufacturing Company (tractors). | Five- to 7-digit numbers. Attachments have from 3- to 6 -digit numbers prefixed or suffixed by various single letters. |
| Caterpillar Tractor Company | One digit followed by a single letter followed by a 4-digit number. Some few parts bear old numbers which are simply 5 - or 6 -digit numbers, or 4-digit numbers prefixed by the letters L or S . |
| Chrysler Corporation | Four- to 7-digit numbers. |
| International Harvester Company . | Four- or 5-digit numbers suffixed by the letters, D, DA, DAX, DX, DXA, or H. |
| R. G. LeTourneau, Incorporated.- | One- to 4-digit numbers prefixed by the letters C, D, E, F, H, L, or R. |
| P and H Company | Two-digit number followed by the letters H , K, N, P, or T, followed by a 3 - or 4 -digit number. |
| Wallace-Tiernan, Incorporated.--- | One- to 4-digit numbers prefixed by the letters $P, \mathrm{U}, \mathrm{R}, \mathrm{CPC}, \mathrm{CPU}, \mathrm{CPW}, \mathrm{CU}$, CUR, CUW, CUX, or WPP. |
| Wisconsin Company------------ | One- to 4 -digit numbers prefixed by a 2 letter symbol. |

## Section III. USAF AIRCRAFT AND AIRFIELD DATA

## 15. USAF Airfield and Aircraft Characteristics

The major types of theatre airfields, the critical types of USAF aircraft for cach, and certain characteristics of these aircraft are given in table 16.

## 16. Aiffield Requirements

a. Allowances uscd to determine the overall requirements for the logistical planning of airbase and airfield structures are given in table 17.
b. Labor and tonnage requirements for airfield construction and reconstruction are given in table 18.
c. Typical airfield construction quantities are given in table 19.

| Airfeld type | Aircraft type | Critical type USAF designation | Gross weight (pounds) | Maximum wheel load (pounds) | Maximum tire pressure (psi) | Overall dimensions (feet) |  |  |  |  | $\begin{gathered} \text { Takeoff } \\ \text { ground } \\ \text { ruu } \\ \text { (fect) } \\ \text { @ sea } \\ \text { level and } \\ 59^{\circ} \mathrm{F} . \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | Length | Wing span. | Height | Tread |  |  |
|  |  |  |  |  |  |  |  |  | $\underset{\text { gear }}{\text { Main }}$ | Outer gear |  |
| Forward cargo (short-time use). | Medium cargo. | C-119C | 73,200-..---- | 31,500---- | 69.6-- - - | 86. 5 | 109. 3 | 26. 5 | 32.3 | NA | 2, 640 |
| Forward cargo (extended use). | Heavy cargo-- | $\mathrm{C}-124 \mathrm{C}$ | 185,000 - - -- | 86,000 $\ldots$ - - | 78.0 . . - - | 130. 0 | 174. 1 | 48. 3 | 37. 3 | NA | 5, 520 |
| Forward tactical | Fighter...- | F-101A | (1) | (1) | (1) | 67.5 | 39.8 | 18. 0 | (1) | NA | (1) |
| Medium bomber--- | Medium bombers. | B-47E | 200,000 .-. -- | Rear assembly load 103,200. | Front 181.2; Rear 189.5 . | 107. 1 | 116. 0 | 28. 0 | NA | 44. 3 | 8, 050 |
| Heavy bomber---- | Heavy bomber. | $\begin{aligned} & \text { B-52 } \\ & \text { B \& D } \end{aligned}$ | Over 400,000_- | Rear <br> assembly <br> load over $200,000 .$ | (1) | 156. 5 | 185. 0 | (1) | NA | 148. 4 | (1) |

${ }^{1}$ Classifed.

Table 17. Airbase and Airfield Allowances

| Facility | Unit of measure | Construction standard |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Field ${ }^{\text {I }}$ |  | Intermediate ${ }^{2}$ |  | Temporsry ${ }^{3}$ |  |
|  |  | Officers | Airmen | Officers | Airmen | Officers | Airmen |
| Spaee Allowanees: Quarters | Square feet per person | 80 | 40 | 80. 0 | 40. 0 | 80.0 | 40. 0 |
| Kitchen | Square feet per person | (4) | (4) | 6. 0 | 4. 0 | 7. 5 | 5. 0 |
| Dining facilities: Family style | Square feet per person | (4) | (4) | 12. 0 | 8. 0 | 15. 0 | 10. 0 |
| Cafeteria style. | Square feet per person | (4) | (4) | 6. 0 | 4.0 | 7.5 | 5. 0 |
| Unit administration | Square feet per person. | 2 | 2 | 2. 0 | 2. 0 | 3. 0 | 3. 0 |
| Unit supply | Square feet per person. | 2 | 2 | 2. 0 | 2. 0 | 3. 0 | 3. 0 |
| Unit recreation and welfare | Square feet per person. | 61 | $4$ | $\begin{aligned} & 6.0 \\ & \text { 1. } 0 \end{aligned}$ | $\begin{aligned} & 4.0 \\ & 1.0 \end{aligned}$ | $\begin{aligned} & 9.0 \\ & 1.0 \end{aligned}$ | 6. 01. 0 |
| Unit medical. | Square feet per person. |  |  |  |  |  |  |
| Sanitary Installations: Toilet seat and urinals. | Persons per fixture. | (4) | (4) | 10. 0 | ${ }^{5} 20.0$ | 10. 0 | ${ }^{5} 20.0$ |
|  | Square feet per seat and urinal ${ }^{8}$-- -- |  |  | 25.0 | 25.0 | 25.0 | 25. 0 |
| Showers | Persons per head. | (4) | (4) | 10. 0 | 20.0 | 10.0 | 20.0 |
|  | Square feet per head |  |  | 50.0 | 50.0 | 50.0 | 50.0 |
| Lavatory | Persons per fixture. | (4) | (4) | 5. 0 | 10.0 | 5. 0 | 10.0 |
|  | Square feet per fixture |  |  | 15.0 | 15.0 | 15. 0 | 15. 0 |
| Serub deek or laundry----------- | Square feet per person. | (4) | (4) | 2. 0 | 2. 0 | 2. 0 | 2. 0 |
| Water Allowances: Kitehens.---.-- | Gallons per person per day | (4) | (4) | 5. 0 | 5. 0 | 5. 0 | 5. 0 |
| Showers and lavatories. | Gallons per person per day | (4) | (4) | 20.0 | 20.0 | 20. 0 | 20.0 |
| Latrines. | Gallons per person per day | (4) | (4) | 0.0 | 0.0 | 10.0 | 10.0 |
| Lighting Allowances: Quarters----- | Watts per square foot.-...--------- | (4) | (4) | 0.4 | 0.4 | 0.4 | 0. 4 |
| Kitchens | Watts per square foot.....-...---.-- | (4) | (4)$(4)$ | 0. 6 | 0. 6 | 0. 6 | 0. 6 |
| Dining faeilities_------------------1) | Watts per square foot-------- | (4) |  |  |  |  |  |


| Facllity | Unit of measure | Constructlon standard |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Field ${ }^{1}$ |  | Intermediate ${ }^{\text {a }}$ |  | Temporary ${ }^{\text {s }}$ |  |
|  |  | Officers | Airmen | Offleers | Atrmen | officers | Airmen |
| Unit administration----.---------- | Watts per square foot.-.........-.-- | ${ }^{4}$ ) | (4) | 1. 0 | 1. 0 | 1. 0 | 1. 0 |
| Unit supply | Watts per square foot Watts per square foot. | (4) | (4) | 0.2 | 0. 2 | 0. 2 | 0. 2 |
| Unit recreation and we |  | $\left.{ }^{4}\right)$ | (4) | 1. 2 | 1. 2 | 1. 2 | 1. 2 |
| Showers. | Watts per square foot | (4) | (4) | 0. 3 | 0. 3 | 0. 3 | 0.3 |
| Lavatories | Watts per square foot | (4) | (4) | 1. 6 | 1. 6 | 1. 6 | 1. 6 |
| Toilet seats and urinals | Watts per square foot. | (4) | (4) | 0.2 | 0.2 | 0. 2 | 0.2 |

I This is equivalent to OCE Construction Standard No. 2.
${ }^{2}$ This is equivalent to OCE Construction Standard No. 4.
${ }^{3}$ This is equivalent to OCE Construction Standard No. 6.

4 Not applicable.
5 Reduce to 15 persons per fixture for WAF
6 For trough urinals, 2 fcet of trough equals one urinal

Table 18. Airfield Labor and Tonnage Requirements

| Alrfield type and eritieal aireraft | New Construction ${ }^{1}$ |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Engineer battalion-months ${ }^{2}$ |  |  | Construction supplies ${ }^{3}$ |  |
|  | Stage I | Stage II | Stage III | Mcasurement tons | Short tons |
| Forward eargo, medium $\mathrm{C}-119 \mathrm{C}$ (one wing) | 2. 5 | 11.0 |  | 1,200 | 1, 200 |
| Forward cargo, heavy C-124C (one wing) |  |  | 15. 0 | 3, 000 | 3, 000 |
| Forward taetieal $\mathrm{F}-101 \mathrm{~A}$ (one wing) | 6. 0 | 9.0 | 13. 0 | 9, 000 | 9, 000 |
| Medium bomber B-47E (one wing) | 11. 0 | 16. 0 | 27.0 | 35, 000 | 24, 000 |
| Heavy bomber B-52 B and D (one wing) | 12. 0 | 18. 0 | 30. 0 | 50, 000 | 35,000 |

[^4]Table 19. Typical Airfield Construction Ouantities

|  | $\begin{array}{\|c} \text { Surfaced } \\ \text { area (square } \\ \text { yards) } \end{array}$ | $\begin{array}{\|c} \text { Graded area } \\ \text { (square } \\ \text { yards) } \end{array}$ | Base coursc (cubic yards) | Asphalt (gallons) | $\begin{aligned} & \text { Chips } \\ & \text { (cubic } \\ & \text { yards) } \end{aligned}$ | Stripping (cubic yards) | Excavation (cuhic yards) | $\underset{\text { yards) }}{\substack{\text { Fill (cubic } \\ \text { y }}}$ | $\begin{aligned} & \text { Rock } \\ & \text { (cubic } \\ & \text { yards) } \end{aligned}$ | $\begin{aligned} & \text { Culverts } \\ & \text { (fect) } \\ & \text { (diam- } \\ & \text { ctcr } \\ & \text { inches) } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Runway (paved $10,000 \mathrm{ft}$. by 300 ft | 333, 300 | 769, 250 | 100, 000 | 249, 800 | 3,320 | 92, 300 | 307, 700 | 246, 200 | 4,350 | ------ |
| Runway (paved 6,500 ft. by 150 <br> ft) $\qquad$ | 108, 300 | 250, 000 | 32, 500 | 81, 200 | 1, 080 | 30, 000 | 100, 000 | 80, 000 | 1, 350 |  |
| Main taxiway--------------------------- | 41, 500 | 64, 200 | 12, 400 | 24, 900 | 420 | 7,000 | 35, 000 | 29, 000 |  | 200-36 |
| Apron access taxiway----------- | 17, 700 | 28, 400 | 5, 300 | 10,600 | 180 | 6, 000 | 30, 000 | 25, 000 |  | 300-36 |
| Hardstand area warmup apron, taxiway $\qquad$ | 14,500 | 23, 200 | 4, 400 | 8,700 | 150 |  |  |  |  |  |
| Circulation taxiways.----- | 3,900 | 6,200 | 1,200 | 2,300 | 40 | 1,000 | 2,000 | 2,000 17,000 |  |  |
| Main transport apron | 72, 200 | 82, 300 | 21,700 | 43, 300 | 720 | 17, 000 | 20, 000 | 17,000 8,000 |  | 210-36 |
| Servicc apron----- | 17, 800 | 21, 200 | 5,300 | 10,700 | 180 | 7, 000 | 10, 000 | 8,000 4,000 |  | 210-36 |
| Warmup apron | 4, 400 | 5,100 | 1,300 | 2,600 | 40 | 2,000 3,000 | 5, 000 | 4,000 4,000 |  |  |
| Drum-fill arca | 9, 600 | 10, 000 | 1, 600 |  |  | 3, 000 | 6,000 | 4,000 |  |  |
| Transport hardstands.--.------- | 5,800 68,000 | 10,000 111,500 | 1,700 11,300 | 3, 500 | 60 | 4,000 | 25, 000 | 20, 000 |  | 200-18 |
| Roads. | 68, 000 | 111, 500 | 11,300 |  |  | 4,000 | 25, 000 |  |  |  |
| Total ${ }^{1}$ | \{363, 700 | 612, 100 | 98, 700 | 187, 800 | 2, 870 | 77,000 | 233, 000 | 189, 000 | 1,350 | $710-36$ $200-18$ |

[^5]
## 17. Data on Hangars

Data on hangars are given in table 20.

## 18. Characteristics of Portable Airfield Surfacing

Characteristics of portable airfield surfacing are given in table 21.

> Table 20. Hangars

| Type building | Size (feet) | Short tons | Measurement |
| :---: | :---: | :---: | :---: |
| Butler type CH , canvas roof and doors_ | 130 by 160 | 75.0 | 112.0 |
| Butler combat hangar, type CHS, steel and canvas doors. | 130 by 160 | 95. 0 | 135.0 |
| Butler combat hangar, type CHS, with steel sliding doors. | 130 by 160 | 110.0 | 145. 0 |
| Luria catenary tent | 130 by 160 | 33. 0 | 64. 0 |
| Luria eatenary tent | 130 by 96 | 22. 0 | 43. 0 |
| OCE design: <br> 3 -hinged areh, TO 12, 17 metalsheathed eanvas doors. | 130 by 160 | 98.0 98.0 | 85.0 125.0 |
| Shed type hangar ( 55 feet by multiples of 32 fect, TO 12, 124): Per basic unit. | 32 by 55 | 19.0 | 23.0 |
| Per cxtension unit | 32 by 55 | 10.3 | 14. 5 |

Table 21. Characteristics of Portable Airfield Surfacing

| Type | PSP (10 ga) | M-6 (10 ga) | M-8 (10 ga) | $\operatorname{PAP}\left(3 / 78^{\prime \prime}\right)$ | $\mathrm{M}-9$ (3/8 $\mathrm{s}^{\prime \prime}$ ) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Unit wcight and dimensions: |  |  |  |  | 3.7 |
| Weight (pounds per square feet) - - | 5.1 | 5.4 | 7.3 | 2.54----------- | 3.7. <br> 11'93/' |
| Length ------- | 10'0' ${ }^{\prime \prime}$---------- | $10^{\prime} 0^{\prime \prime}$ | 11/93/4' ${ }^{\prime \prime}{ }^{\prime} 1^{\prime \prime}$------ | 10'0' ${ }^{\prime \prime}$ |  |
| Width | $1^{\prime} 3^{\prime \prime}$----------- | $1^{\prime} 3^{\prime \prime}$ | $1^{\prime} 71 / 2^{\prime \prime}$ - | $1^{\prime}{ }^{\prime \prime}$ | $110 \%{ }^{\text {. }}$ |
| Depth | $78^{\prime \prime}$ | $78^{\prime \prime}$ | $1^{\prime 1} 18^{\prime \prime}-$ | 12.5 | 11/2.8. |
| Placing area-1 panel (square feet) - | 12.5 | 12.5 | 19.2 | 12.5 | 21.8. |
| Bundles: |  |  | 14 plan | 30 planks | 14 planks. |
| Number of units--------------- | 30 planks ${ }^{1}$ | 30 planks | 14 plank | 375------ | 305.2. |
| Square feet placing in 1 bundle Gross $^{\text {a }}$ - | 375.- | 375-..--------------- | 268.8----------------- | 375 975 | 1,120. |
| Gross weight per bundle (pounds) -- | 1,928 | 2,055--------- | 1,960 | 975 | 1,120. |
| Bundic dimensions, width, length, height $\qquad$ | $\begin{gathered} 1^{\prime} 41_{2}^{\prime \prime} \text { by } 10^{\prime} 0^{\prime \prime} \\ \text { by } 1^{\prime} 2^{\prime \prime} . \end{gathered}$ | $\begin{array}{r} 1^{\prime} 41^{\prime \prime \prime} \text { by } 10^{\prime} \\ 134^{\prime \prime} \text { by } 1^{\prime} 2^{\prime \prime} . \end{array}$ | $\begin{gathered} 1^{\prime} 101^{\prime \prime 2^{\prime \prime}} \text { by } 12^{\prime} 1^{\prime \prime} \\ \text { by } 1^{\prime} 0^{\prime \prime} . \end{gathered}$ | $\begin{aligned} & 1^{\prime} 5^{\prime \prime} \text { by } 10^{\prime} 0^{\prime \prime} \text { by } \\ & 1^{\prime} 3^{\prime \prime} \end{aligned}$ | $\begin{aligned} & 2^{\prime} 3^{\prime \prime} \text { by } 12^{\prime} 1^{\prime \prime} \text { by } \\ & 1^{\prime} 33 / 4^{\prime \prime} \\ & 35.6 . \end{aligned}$ |
| Volume-1 bundle (cubic feet).-.-- | 16.0---------- | 16.3---------- | 22.7 | 17.7 |  |
| Requirements for 5,000 by $150^{\prime}$ runway: |  | 2,000 | 2,790..-.------ | 2,000 | 2,450. |
| Quantity (bundles or rolls) <br> Weight (tons) | 2,000------------- | 2,000- | 2,790--------------- | 975.- | 1,376. |
| Cargo space (cubic feet) | 32,084-...---- | 32,552 | 63,333 - .-...-- | 35,418 | 87,505. |
| Ship tons (40 cubic feet cquals 1 ship ton) $\qquad$ | 802.10-------- | 813.80-------- | 1,583.25------- | 885.45-.------ | 2,188. |
| Cargo density (pounds per cubic feet gross weight) | 120.18 | 126.26 | 86.34 | 55.06_ | 31.46. |
| Area covered per cubic feet cargo space. | 23.376_------- | 23.040 | 11.8415 | 21.176 | 8,573. |
| Average laying speed (square feet per man-hour) $\qquad$ | 125----------- | 60-75 ${ }^{2}$ | $150{ }^{2}$ | 150 | $175 .{ }^{2}$ |

[^6]
## Section IV. U.S. ARMY AIRCRAFT AND AIRFIELD DATA

## 19. Army Aircraft Characteristics

The major types of Army aircraft and certain of their characteristies are given in table 22.

## 20. Army Airfield Design Criteria

Design criteria for Army airfields are given in table 23. For flightway and flightstrip nomenclature, see figures 1 and 2.


Figure 1. Flightstrip nomenclature.


Figure 2. Flightway nomenclature.

## 21. Army Heliport Design Criteria

Army heliport design criteria are given in table 24.

FIXED-WING AIRCRAFT (AIRPLANES)

| Alreraft type | Army designation | $\begin{gathered} \text { Qross } \\ \text { welght } \\ \text { (pounds) } \end{gathered}$ | Maximum wheel load (pounds) | $\begin{gathered} \text { Tlre } \\ \text { pressure } \\ \text { (pounds } \\ \text { per square } \\ \text { ineh) } \end{gathered}$ | Overall dimensions |  |  |  | Takeoff ground run (TGR): Seal level, $59^{\circ} \mathrm{F}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Length | Wingspan | Helght | Tread |  |
| Observation | L-19 (Bird Dog) | 2, 400 | 1, 150 | 22 | $22^{\prime} 0^{\prime \prime}$ | $36^{\prime} 0^{\prime \prime}$ | $9^{\prime} 2^{\prime \prime}$ | $7^{\prime} 5^{\prime \prime}$ | 421 |
| Utility | L-20 (Beaver) | 4,820 | 2, 350 | 25 | $30^{\prime} 4^{\prime \prime}$ | $48^{\prime} 0^{\prime \prime}$ | $10^{\prime} 5^{\prime \prime}$ | $10^{\prime} 2^{\prime \prime}$ | 481 |
| Light transport | U-1 (Otter) | 7, 600 | 2,850 | 28 | $41^{\prime} 10^{\prime \prime}$ | $58^{\prime} 0^{\prime \prime}$ | $12^{\prime} 7^{\prime \prime}$ | $11^{\prime} 2^{\prime \prime}$ | 550 |
| Command.-.- | L-23----- | 6,000 | 2, 700 | 35 | $31^{\prime} 6^{\prime \prime}$ | $45^{\prime} 5^{\prime \prime}$ | $11^{\prime} 4^{\prime \prime}$ | $12^{\prime} 10^{\prime \prime}$ | 1,000 |

ROTARY-WINO AIRCRAFT (HELICOPTERS)

| Alrcraft type | Army designation | $\begin{gathered} \text { Gross } \\ \text { welght } \\ \text { (pounds) } \end{gathered}$ | Maximum wheel load (pounds) | Tire pressure (pounds per square inch) | Overall dimensions |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Length | Rotor dlamete | Helght | Tread |
| Reconnaissance.- | H-13 | 2, 350 | 1, 170 | Skid | $41^{\prime \prime} 5^{\prime \prime}$ | $35^{\prime} 2^{\prime \prime}$ | $9^{\prime} 6^{\prime \prime}$ | $7^{\prime} 6^{\prime \prime}$ |
|  | H-23 | 2, 570 | 1, 285 | Skid | $40^{\prime} 6^{\prime \prime}$ | $35^{\prime} 0^{\prime \prime}$ | $9^{\prime} 9^{\prime \prime}$ | $7^{\prime} 6^{\prime \prime}$ |
|  | H-19 | 8, 100 | 2, 700 | 35 | $62^{\prime} 5^{\prime \prime}$ | $53^{\prime} 0^{\prime \prime}$ | $14^{\prime} 5^{\prime \prime}$ | $11^{\prime} 0^{\prime \prime}$ |
| Cargo-------- | H-40 | 5, 200 | 2, 600 | Skid | $48^{\prime} 9^{\prime \prime}$ | $44^{\prime} 0^{\prime \prime}$ | $14^{\prime} 7^{\prime \prime}$ | $7^{\prime} 101 / 4^{\prime \prime}$ |
|  | H-21 (Light) | 11,520 | 3, 840 | 115 | $86^{\prime} 4^{\prime \prime}$ | $44^{\prime} 0^{\prime \prime}$ | $16^{\prime} 0^{\prime \prime}$ | $13^{\prime} 4^{\prime \prime}$ |
|  | H-34 (Light) | 13,300 | 5, 892 | 55 | $65^{\prime} 10^{\prime \prime}$ | $56^{\prime} 0^{\prime \prime}$ | $15^{\prime} 10^{\prime \prime}$ | $12^{\prime} 0^{\prime \prime}$ |
|  | $\mathrm{H}-37$ (Medium) | 30, 900 | 13,745 |  | $82^{\prime} 10^{\prime \prime}$ | $68^{\prime} 0^{\prime \prime}$ | $21^{\prime} 6^{\prime \prime}$ | $19^{\prime} 9^{\prime \prime}$ |

Table 23. Army Airfield Design Criteria

|  |  | Pioneer ${ }^{1}$ | 1fasty | Deliberate |
| :---: | :---: | :---: | :---: | :---: |
|  | Runway |  |  |  |
|  | Length (to nearest 100 ft .) ; eorrected takeoff ground run multiplied by (safety faetor). | 1.10-- | 1.50 | 1.75. |
| 2 | Width (minimum) | 50 ft . sod or umpaved or 25 ft . shoulcler-toshoulder gravel or better road; open field. | 50 ft | 75 ft . |
| 3 | Shoulder width (minimum) | 0 ft - | 10 ft | 10 ft . |
| 4 | Lateral elearance (width) of flightstrip_ | 150 ft | 200 ft | 300 ft . |
| 5 | Runway surfacing----------- | In-place sod or compacted base course. | Portable | Rigid or flexible pavement. |
| 6 | Longitudinal grade (maximum) | 10 percent | 5 pereent. | 3 percent. |
| 7 | Maximum rate of change in grade per 100 ft . on vertical eurves. | 1.0 percent------------ | 0.5 percent | 0.333 percent. |
| 8 | Minimum sight distanee aeross vertical eurves (height of eye $5^{\prime}$, to a point $5^{\prime}$ above runway surface). | 120 runway length-.-.---- | 500 ft . plus $1 / 2$ runway length. | 500 ft . plus $1 / 2$ runway length. |
| 9 | Minimum distanee PI to PI on vertieal curves_ | $200 \mathrm{ft}^{\text {------------------- }}$ | 600 ft | 800 ft . |
| 10 | Transverse slope (minimum) | Natural surfaee-------- | 1.5 percent | 1.5 pereent. |
| 11 |  | 5 percent-------------- | 3.0 percent.------- | 3.0 percent. |
| 12 | Transverse shoulder slope (minimum) ------- | NA-..---------------- | $1 / 2$ pereent greater than runway transverse slope. | 1/2 pereent greater than runway transverse slope. |
| 13 | Transverse shoulder slope (maximum) ------- | NA | 5.0 percent.-..------- | 5.0 percent. |
| 14 | Parallel runways (minimum spacing, eenter to center). | 200 ft - | 300 ft -.... | $300 \mathrm{ft} \text {. }$ |
| 15 | Cleared areas, maximum slope ee footnote at end of table | Unlimited | 10 pereent. | 10 pereent. |


|  |  | Pioncer ${ }^{1}$ | Hasty | Deliberate |
| :---: | :---: | :---: | :---: | :---: |
|  | taxiways |  |  |  |
| 16 | Width (to nearest 10 ft .) | NA. | 20 ft | 20 ft . |
|  | Landing gear tread multiplicd by - but not. - less than-. | NA | 1.5 | 1.75 |
| 17 | Shoulder width (minimum) | NA | 5 ft | 5 ft . |
| 18 | Lateral clearance, taxiway width plus -- | NA. | Airplane wingspan.. | Airplane wingspan. |
| 19 | Longitudinal grade (maximum) | NA | 6 percent. | 6 percent. |
| 20 | Transverse slope (minimum) | NA | 1.5 percent | 1.5 percent. |
| 21 | Transverse slope (maximum) | NA | 4. percent | 3.0 percent. |
| 22 | Transverse shoulder slope (minimum) | NA. | 0.5 percent greater than taxiway transverse. | 0.5 percent greater than taxiway transversc. |
| 23 | Transversc shoulder slope (maximum) | NA | 5 percent | 5 percent. |
| 24 | Taxiway horizontal curves exccpt at intersections, minimum radius. | NA | 75 ft . | 100 ft . |
|  | hardstands and aprons |  |  |  |
| 25 | Fillets of junction, minimum radius.----.-. | NA. | 0 ft | 10 ft . |
| 26 | Diametcr (minimum) or minimum dimension of square or rectangle. | NA | 30 ft | 30 ft . |
| 27 | Width of hardstand where camouflage is required if manpower is used to move aircraft from taxiway. | NA. | Airplane tread plus 5 ft . | Airplane tread plus 5 ft . |
| 28 | Shoulder width. | NA | 0 ft . | 5 ft . |
| 29 | Minimum spacing, hardstands (center to center). | NA. | 100 ft - | 100 ft . |

30

| 31 | Slopes (any direction) (minimum) |
| :--- | :--- |
| 32 | Slopes (any direction) (maximum) |
| 33 | Area requircd for apron or minimum dispersal |
|  | parking area. Number of airplancs $\times$ |
|  | wingspan $\times$ length $\times$ factor. |

## overrun

Length (from end of runway)
35 Width (at runway end) $\qquad$ NA
NA

## APPROACH ZONE

38 Length (from end of flight strip)
39 Width (at flight-strip end) $\qquad$ 500 ft
Lateral clearance of flight strip.
40 Width, approximate (outer end)
41 Glide angle ratios from end of flight strip: Airfield for day use only $\qquad$
se.Airfield for day and night use Airfield with instrument landing facilities
Note. In the deslgn of Army airfields and hellports or operation of Army alreraft at these locations, there shall be a minlmum of 15 ft . clearance between the pavement edge nearest the runway end or elge and the lower surface of the fight approaeh zone. For coordination with publie highway officials in matters pertaining to airway-highway elearance requirements, refer to SR $55-80-1$.

NA------------------------------

NA ---------------------------
${ }^{1}$ The eriteria deseribed under the heading "Pioneer" do not preelude the unit army aviation offieer from selecting and using an airfield site from whieh he feels he can operate safely, and yet does not meet the minimum eriteria deseribed in table II. "All over" flelds as distingulshed from runways are acceptahle and desirable since they provide inereased area for operation and permit greater use in wet weather because of their ability to distribute traffic.

|  |  | Pioneer ${ }^{1}$ | Hasty | Deliberate |
| :---: | :---: | :---: | :---: | :---: |
| runways (landing area and takeoff area) |  |  |  |  |
|  | Length, reeommended minimum (dependent on type of helieopter and site conditions). | 100 feet. | 300 feet. | 450 feet. |
| 2 | Width.- | 25 feet | 25 feet | 40 feet. |
| 3 | Landing surfaces. | In-plaee sod or eompaeted base course. | In-plaee sod or dustfree portable surface | Flexible or rigid pavement. |
| 4 | Lateral elearance (min.) | 100 feet. | 150 feet | 250 feet. |
| 5 | Grade, in any direction (max.) | 8.0 perent. | 4.0 percent | 3.0 percent. |
| 6 | Transverse slope (min.) | 0 pereent | 1.5 percent | 1.5 pereent. |
| 7 | Shoulder width . | 0 feet | 10 feet. | eet. |
| 8 | Overrun width | None. | Same as runway width plus two shoulders. | Same as runway width plus two shoulders. |
| 9 | Overrun length_ | None | 50 feet | 100 feet. |
| 10 | Shoulder and overrun, grade (max.) --.----- | None | None | 3.5 pereent. |
|  | Parallel or adjacent runways (min.) eenter-toeenter spacing. | 200 feet | 200 feet | 300 feet. |
| 12 | Cleared areas, max. slope | +10 percent.-.-.- | +10 pereent. | +10 per |
| taxiways |  |  |  |  |
| 13 | Width_ | None. | 20 feet. | 30 feet. |
| 14 | Longitudinal grade (max.) - | None | 3.0 percent | 2.0 pereent. |
| 15 | Transverse slope (max.) | None | 3.0 pereent | 3.0 pereent. |
| 16 | Shoulder width_ | NA. | 35 feet | 35 feet. |
| 17 | Shoulder slope (max.) | None | 3.5 pereent | 3.5 pereent. |



## Section V. RAILROAD DATA

## 22. General

Responsibilities regarding railroads are covered in AR 55-650. Railroad bridges are covered in the TM 5-370-series; railroad surveys in the TM $5-235$-series. Details of railroad engineering practice are given in various handbooks in engineer unit libraries.' Railway gages and mileages of the world are given in paragraph 28.

## 23. Rail Shipments of Engineer Equipment

a. General. Large items of engineer motorized and other heavy construction equipment, when shipped by rail assembled or partially assembled and uncrated, are normally loaded lengthwise onto flatcars or drop-end gondolas. For dimensions of such equipment, see paragraphs 10 and 11. For dimensions of standard American railway cars, see FM 55-15.
b. Number of Items Per Car. To find what fraction of a car the item will occupy, divide the length of the car into the length of the item, plus a small allowance for clearance.
c. Loading on Flatcars.
(1) For American mainline railroads and for a flatcar whosc deck is 3 feet 6 inches above the top of the rail (the most common height), the following are the maximum permissiblc widths, at various heights, of any item loaded on the car:

At a height,above.car floor-of-4 . . 1 , 1 r., Maximum parmissible width




If the car deck is higher than 3 feet 6 inches, figures in the first column must be reduced by the amount in excess of 3 feet 6 inches.
(2) For shipments on branch lincs, somewhat lesser maximum heights and widths may have to be used. Clearance diagrams should be consulted before loading equipment.
d. Loading on Gondolas. Information in $c$ above applies, with the qualification that, from the level of the car deck up to the top of the sidcs, the maximum permissible width of a loaded item is 6 inches less than the clcar inside width of the car. This latter is usually 9 fect 0 inches to 9 feet 5 inches, though in some cases it may bc as much as 10 fect 0 inches.

## 24. Tie Lengths and Embankment Widths

Tie lengths and embankment widths for single-track lines of various gages are shown in figure 3. Embankment widths and othcr elements of double-track lines, standard gage, are shown in figure 4. The 13 -foot track spacing, center to center, is satisfactory for tangent track and is normally the minimum spacing used in multitrack layouts


| $\begin{aligned} & \text { GAGE } \\ & \text { FT INS } \end{aligned}$ | LENGTH OF TIES FT INS. | EMBANKMENT WIDTH TANGENT TRACK FT INS. |
| :---: | :---: | :---: |
| 2'.6" OR LESS | 7'0" | $15^{\circ} 0$ |
| $3^{\prime} \cdot 0^{\prime \prime}$ |  |  |
| 3:3" |  |  |
| 3:3\%" (METER) |  |  |
| 3. $53 .{ }^{\text {a }}$ | 7'6" |  |
| 3'.6" |  |  |
| 4.81/2" (STANDARD) | 8'-6" T0 9:0" | 16'0" |
| 5'.0' |  |  |
| $5^{\prime}-3^{\prime \prime}$ | 9'.6" TO 10'0" | 18.0" |
| 5'.6" |  |  |

Figure 3. Cross section, single track.
for both yard and rumning tracks. In eurved traek, it is satisfaetory for slow traffie only, and the spacing is normally incrcased to 14 feet or more in running tracks to allow for overhang of equipment, rocking of ears, and inequalities of superelevation.

## 25. Spacing of Parallel Tracks

Body traeks in yards are normally spaced a minimum of 13 feet on eenters, except that the first body track is 15 feet on eenters from a running track; and ladder tracks are at least 15 fect on centers from any parallel track. Tracks in pairs for operation of locomotive eranes are spaced at least 18 fect on centers.

## 26. Clearances

Overhead clearances and platform heights are measured from the top of the rail; side clearances from the centerline of track. Clearanees below those spccified are dangcrous and require protection by appropriate warning signs or deviees including tclltales for overhead clearanees betwecn 22 fcet and a minimum allowable of 18 fcet. Unless loeal conditions require greater clearanees, standard minimum clearanees are as follows:
a. Overhead. High-voltage wires, 28 feet; other wires, 27 feet; overhead structures, 22 feet.
b. Side. The following side clearanees are the absolute minimum distanccs. Where any side distance is less than 8 feet 6 inches, it should be posted along the appropriate line and on clearance diagrams.


Figure 4. Cross section, double track.
(1) Canopies up to 15 feet 6 inches high, 8 feet 6 inches.
(2) Canopics higher than 1 feet 6 inches, 5 feet 6 inchcs.
(3) Buildings, 8 feet 6 inches.
(4) Platforms 3 feet 9 inches high, 6 feet 2 inches.
(5) Refrigerator platforms 3 feet 2 inches high, 6 feet 2 inches.
(6) Refrigerator platforms 4 fect 7 inches high, 8 feet 6 inches.
(7) Low platforms 4 inches high, 5 feet 0 inches.
c. Enginehouse Entrances.
(1) Overhead, 17 feet 0 inches.
(2) Side, 6 feet 6 inches.
d. Bridges and Tunnels. Standard single-track bridge and tunnel clearances arc slown in figure 5.

## 27. Materials for Standard-Gage Track

a. Rail. The new and used rail and accessories in the Department of the Army Supply Manual, SM 5-5, is the 75 -pound-per-yard ASCE section, but this when depleted will be replaced by the 85pound ASCE section in 39 -foot lengths.
b. Ties. Ties listed in SM 5-5 are 6 by 8 inches, 8 fect long, for untreated crossties; and 7 by 9 inches, 8 feet long, for creosoted crossties, until depleted. Thereafter, the standard width of issue will be 8 feet 6 inches. Ties are produced locally if possible and may be creosoted if it is necessary to produce them in the United States for shipment overseas. Switch ties are listed in the same sizes by plan lengths,


Figure 5. Standard single-track bridge and tunnel clearances.
in sets for number 8 turnouts. The enginccring manual for Dcpartment of the Army construction provides minimum sizes of 7 by 9 inclies for switch tics and 8 by 8 inches, 10 fcet long, for bridge tics. Standard spacing is 19 and 21 ties per 39 -foot rail for yard and running tracks, respectively.
c. Tie Plates, Spikes, and Bolts. Stccl tie plates, 9 by 6 by $3 / 8$ inches in size, are authorized for all track but may be omitted in hasty construction except at turnouts and sharp curves. Spikes arc issucd in the $9 / 16^{-}$by $51 / 2$-inch size, and track bolts in $7 / 8$ - by 4 -inch and $7 / 8$ - by $41 / 2$ inch sizes.
d. Ballast. Crushed rock, slag, or gravel, in sizes graded from 3-inch to number 10 sicve, is bcst. Coarse cinder ballast is satisfactory for yard tracks and sidings and is brought to the tops of the ties to provide good footing for operating personnel. The cngincering manual specifies a minimum depth of 8 inches under the ties, but as little as 4 inches can be used in hasty construction. The top of the ballast should clear the bottom of the rails by at least 1 inch. Ballast is produced locally wherever possible.
$e$ Turnouts. The standard turnout is issucd unassembled and is complete with low-stand throw and rigid-bolted number 8 frog. Dimensions and layout information for turnouts and crossovers using various frogs from number 6 to number 18 are given in figure 6 .

## 28. Foreign Railroad Gages and Mileages

Standard gage, 4 feet $8 \frac{1}{2}$ inches ( $561 / 2$ inches), is in general use in the United States. Table 25 gives the latest available information on foreign gages.


| DIMENSIONS OF FROGS, SWITCHES, TURNOUTS AND CROSSOVERS |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0 <br> 2 <br> 2 <br> 0 <br> 0 <br> $\mathbf{Z}$ | frogs |  | SWITCHES |  | LEAD CURVE |  | TURNOUTS AND CROSSOVERS |  |  |  | * |  |
|  | 世 <br> $\mathbf{0}$ <br> $\mathbf{Z}$ <br> $\mathbf{8}$ <br> 0 <br> 0 | $\begin{aligned} & \text { 도 } \\ & 0 \\ & \text { Z } \\ & 巴 \\ & 0 \\ & 0 \\ & \hline \mathbb{Z} \end{aligned}$ |  |  | 4 <br> 0 <br> 0 <br> 0 <br> 0 <br> 0 |  | DISTANCE IN fEET 8ETWEEN CENTER LINES Of TRACKS-GAGE-4'-8 $\quad 1 / \mathbf{2}^{\prime \prime}$ |  |  |  |  |  |
|  |  |  |  |  |  |  | $13^{\prime} \cdot 0^{\prime \prime}$ |  | 14'0' ${ }^{\prime \prime}$ |  |  |  |
|  |  |  |  |  |  |  | A | 8 | A | B | A | B |
| 6 | $9^{\circ} 31^{\prime} 38^{\prime \prime}$ | 10'0'0 | 11'0" | 47'.6" | 258.57 | $22^{\circ} 17^{\prime} 58^{\prime \prime}$ | 20'5 1/2' | 21'6 1/2" | 26'.5" | 27'.7' | $5^{\prime} \cdot 11^{-1 / 1 / 2}$ | $6^{\prime} 01 / 2^{\prime \prime}$ |
| 7 | $8^{\circ} 10^{\prime} 16^{\prime \prime}$ | 12'0" | 16'.6' | 62'17 | 365.59 | $15^{\circ} 43^{\prime} 16^{\prime \prime}$ | $24^{\prime}-03 / 8^{\prime \prime}$ | 24'11 5/8' | 30'-11 15/16" | 32'0 1/16" | $6^{\prime}-119 / 16^{\prime \prime}$ | $7^{\prime} .0$ 7/16 ${ }^{\prime \prime}$ |
| 8 | $7^{\circ} 09^{\prime} 10^{\prime \prime}$ | 13'0" | 16'6" | 68'-0" | 487.28 | $11^{\circ} 46^{\prime} 44^{\prime \prime}$ | 27'.7 1/8" | 28'-4 7/8' | $35^{\prime}-6$ 3/4" | $36^{\prime} .51 / 4^{\prime \prime}$ | $7^{\prime}-11$ 5/8" | $8^{\prime} .0$ 3/8' ${ }^{\prime \prime}$ |
| 9 | $6^{\circ} 21 \times 35^{\prime \prime}$ | 16'0" ${ }^{\prime \prime}$ | 16.6" | 72'-3 1/2" | 615.12 | $9^{\circ} 19^{\prime} 30^{\prime \prime}$ | $31^{\prime}-15 / 8^{\prime \prime}$ | 31'-10 3/8" | 40'.1 $5 / 16^{\prime \prime}$ | 40'.10 11/16" | $8^{\prime} .1111 / 16^{\prime \prime}$ | $9^{\prime}-0$ 5/16 ${ }^{\prime \prime}$ |
| 10 | $5^{\circ} 43^{\prime} 29^{\prime \prime}$ | 16'.6" | 16.6" | 78'.9' | 779.39 | $7^{\circ} 21^{\prime} 24^{\prime \prime}$ | 34'8 1/8'8 | 35'3 7/8" | 44'.7 13/16" | 45'-4 3/16" | $9^{\prime} .1111 / 16^{\prime \prime}$ | $10^{\prime} .0$ 5/16" |
| 12 | $4^{\circ} 46^{\prime} 19^{\prime \prime}$ | $20^{\prime}-4^{\prime \prime}$ | 22.0" | 96'.8" | 1104.63 | $5^{\circ} 11^{\prime} 20^{\prime \prime}$ | $41^{\prime} .83 / 4^{\prime \prime}$ | 42'-3 1/4" | 53'-8 1/2" | 54'3 1/2" | 119.11 3 /4" | $12^{\prime} .01 / 4^{\prime \prime}$ |
| 14 | $4^{\circ} 05^{\prime} 27^{\prime \prime}$ | 23'-7" | 22'.0" | $107^{\prime} .03 / 4^{\prime \prime}$ | 1581.20 | $3^{\circ} 37^{\prime} 28^{\prime \prime}$ | $48^{\prime \prime} .91 / 4^{\prime \prime}$ | $49^{\prime}-213 / 16^{\prime \prime}$ | 62'.9 1/16" | $63^{\prime}-31 / 16^{\prime \prime}$ | $13^{\prime} .1113 / 16^{\prime \prime}$ | $14^{\prime} .01 / 4^{\prime \prime}$ |
| 16 | $3^{\circ} 34^{\prime} 47^{\prime \prime}$ | 26'0" | 30'0" | $131{ }^{\prime} 4^{\prime \prime}$ | 2007.12 | $2^{\circ} 57^{\prime} 18^{\prime \prime}$ | 55'.9 5/8" | $56^{\prime} .21 / 2^{\prime \prime}$ | 71.9 7/16" | $72^{\prime}-2$ 11/16" | 15'.11 13/16" | $16^{\prime}-03 / 16^{\prime \prime}$ |
| 18 | $3^{\circ} 10^{\prime} 56^{\prime \prime}$ | 29'-3" | 30'0' | $140^{\prime} .111 / 2^{\prime \prime}$ | 2578.79 | $2^{\circ} 13^{\prime} 20^{\prime \prime}$ | 62'.9 7/8" | $63^{\prime}-23 / 16^{\prime \prime}$ | 80'.9 11/16" | $81^{\prime}-23 / 8^{\prime \prime}$ | 17'-11 13/16" | $18^{\prime} .03 / 16^{\prime \prime}$ |
| 4 COLUMNS a \& 8 under Q Give the amounts to add to tabular figures for EVERY ONE (I) FOOT INCREASE IN DISTANCE BETWEEN TRACKS |  |  |  |  |  |  |  |  |  |  |  |  |

Figure 6. Frogs and switches in turnouts and crossovers.

Table 25. Foreign Railroad Gages and Mileages


Table 25. Foreign Railroad Gages and Mileages-Continued


Table 25. Foreign Railroad Gages and Mileages—Continued

| Country | Track gage |  | Total length of railroads |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Inches | Meters | Mules | Kilometers |
| Indochina: |  |  |  |  |
| Cambodia_ | $39 \% 8$ | 1. 000 | 240 | 384 |
| North Viet-Nam_ | 39\%\% | 1. 000 | 60 | 96 |
| South Viet-Nam_ | $39 \%$ | 1. 000 | 780 | 1, 248 |
|  | 31\% | . 800 | 22 | 35 |
| Iran.---------------- | 56\% | 1. 434 | 1, 470 | 2, 352 |
|  | 60 | 1. 524 | 124 | 198 |
|  | 66 | 1. 677 | 57 | 91 |
|  | 393/8 | 1. 000 | 5. 6 | 9 |
|  | 30 | . 762 | 35.8 | 57 |
|  | 393/s | 1. 000 | 722 | 1, 155 |
|  | $56 \%$ | 1. 434 | 328 | 524 |
|  | $56 \frac{1}{2}$ | 1. 434 | 162. 8 | 260 |
| Israel-------------- | +1516 | 1. 050 | 12. 4 | 19 |
|  | Dual | Dual | 54 | 86 |
| Japan-------------- | 42 | 1. 067 | 15, 295 | 24,614 |
|  | 30 | . 762 | --------- | -- |
|  | 54 | 1. 372 | 1,005 | 1, 617 |
|  | 561/2 | 1. 434 | ------- | ----- |
| Jordan <br> Kiorea: <br> North $\qquad$ | 4138 | 1. 050 | 225 | 360 |
|  |  |  |  |  |
|  | 5612 | 1. 434 | ], 629 | 2, 716 |
|  | 30 | . 762 | 608 | 1, 014 |
|  | $561 \frac{1}{2}$ | 1. 434 | 1, 750 | 2, 800 |
| South | 30 | . 762 | $\begin{gathered} 150 \\ \text { (about.) } \end{gathered}$ | 240 |
|  | 561/2 | 1. 434 | 203 | 324 |
|  | $413 / 8$ | 1. 050 | 51 | 81 |
|  | 393/8 | 1. 000 | 984 | 1, 574 |
| Mongolia | 6039 | 1. 524 | 355 | 568 |
|  |  | 1. 000 | 331 | 529 |
|  |  | . 700 | 24 | 38 |
|  | 30 | . 762 | 64 | 102 |
| Pakistan: |  |  |  |  |
| West,East_ | 66 | 1. 677 | 4, 546 | 7,273 |
|  | 3938 | 1. 000 | 319 | 510 |
|  | 30 | . 762 | 458 | 732 |
|  | 66 | 1. 677 | 542 | 867 |
| East | 3938 | 1. 000 | 1. 118 | 1, 788 |
|  | 30 | . 762 | 20 | 32 |
| Saudi Arabia_------ | 561/2 | 1. 434 | 351 | 561 |
| Syria | 561/2 | 1. 434 | 349 | 558 |
|  | $413 / 8$ | 1. 050 | 189 | 302 |
| Thailand (Siam) | 393/8 | 1. 000 | 2, 045 | 3,272 |
| Turkey----.--- | 5612 | 1. 435 | 4, 58:3 | 7, 332 |
|  | 291/2 | . 750 | 76 | 121 |
|  | 60 | 1. 524 | 76 | 121 |

Table 25. F'orcign Railroad Gages and Mileages-Continued

| Country | Track gage |  | Total length of railioads |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Inclies | Meters | Miles | Nilometers |
| Union of Sovict Socialist Republics (statistics are estimates) | 60 | 1. 524 | 74,500 | 119, 200 |
| Africa: |  |  |  |  |
| Algeria | 561/2 | 1. 434 | 1, 409 | 2, 254 |
|  | 41\% 6 | 1. 050 | 795 | 1, 272 |
|  | 393/8 | 1. 000 | 421 | 673 |
|  | 2:358 | . 600 | 90 | 144 |
| Angola------------------- | 42 | 1. 067 | 992 | 1, 587 |
|  | 393/8 | 1. 000 | 403 | 644 |
|  | ${ }^{1} 42$ | 1. 067 | 77 | 123 |
| Bechuanaland (included in fig-. ures for Rhodesia). <br> Belgian Congo_ |  |  |  |  |
|  | 42 | 1. 067 | 1, 767 | 2, 827 |
|  | 393/8 | 1. 000 | 522 | 835 |
|  | 24 | . 609 | 87 | 139 |
|  | 235\% | . 600 | 528 | 844 |
| British Somaliland (no railroads). |  |  |  |  |
| Egypt <br> Eritrea | 5612 | 1. 434 | 2, 900 | 4, 640 |
|  | 3938 | 1. 000 | 168 | 268 |
|  | 30 | . 762 | 870 | 1, 392 |
|  | 373/8 | . 950 | 190 | 304 |
| Ethiopia and French Somaliland | $39 \% 8$ | 1. 000 | 490 | 784 |
| French Cameroons-------.--- | 393/8 | 1000 | 313 | 500 |
| French Somaliland (included with Ethiopia). | 42 | 1. 067 | 327 | 523 |
|  |  |  |  |  |
| French West Africa---------- | $393 / 8$ | 1. 000 | 2, 343 | 3, 748 |
| Gambia (no railroads). |  |  |  |  |
| Ghana (Gold Coast) --------- | 42 | 1. 067 | 535 | 856 |
| Italian Somaliland (no railroads). |  |  |  |  |
| Kenya (East African railways and harbors), includes |  |  |  |  |
| Uganda, Kenya, and Tanganyika. | $393 / 8$ | ${ }^{2} 1.000$ | 3,245 | 5, 192 |
| Liberia-------------------- | 42 | 1. 067 | 42 | 67 |
| Jibya | 37713 | . 950 | 102 | 163 |
| Madagascar | $393 / 8$ | 1. 000 | 530 | 848 |
| Mauritius | 561/2 | 1. 434 | 100 | 160 |
| Morocco | 561/2 | 1. 434 | 1, 064 | 1, 702 |
| Mozambique------------------1 | 42 | 1. 067 | 2, 183 | 3,492 |
|  | 291/2 | . 750 | 141 | 225 |

See footnotes at end of table.

Table 9.5. Forcign Railroad Gages and Mileages-Continued


See footnotes at end of table.

Table 25. Foreign Railroad Gages and Mileages-Continued

| Country | Track gage |  | Total length of railroads |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Inches | Meters | Miles | Klometers |
| Chile------------------------ | 66 | 1. 677 | 1, 808 | 2, 886 |
|  | 561/2 | 1. 434 | 504 | 806 |
|  | 42 | 1. 067 | 440 | 704 |
|  | 393/8 | 1. 000 | 2, 429 | 3, 886 |
|  | 30 | . 762 | 181 | 289 |
|  | 235\%8 | . 600 | 193 | 308 |
| Colombia-------------------- | 393/8 | 1. 000 | 904 | 1, 446 |
|  | 36 | . 914 | 487 | 779 |
| Ecuador--------------------- | 501/2 | 1. 434 | 94 | 150 |
|  | 42 | 1. 067 | 500 | 800 |
|  | 291/2 | . 750 | 112 | 179 |
|  | $\left.{ }^{3}\right)$ | $\left.{ }^{3}\right)$ | 122 | 195 |
| Freneh Guiana (no railroads). <br> Paraguay <br> Peru |  |  |  |  |
|  | 561/2 | 1. 434 | 312 | 499 |
|  | 393/8 | 1. 000 | 59 | 94 |
|  | 317/8 | . 800 | 57 | 91 |
|  | 30 | . 762 | 144 | 230 |
|  | 291/2 | . 750 | 67 | 107 |
|  | 24 | . 609 | 11 | 17 |
|  | 561/2 | 1. 434 | 1, 148 | 1, 836 |
| Peru---------------------- | 42 | 1. 067 | 58 | 92 |
|  | 36 | . 914 | 734 | 1, 174 |
|  | 30 | . 762 | 42 | 67 |
|  | 291/2 | . 750 | 27 | 43 |
|  | 235/8 | . 600 | 151 | 241 |
| Surinam (Dutch Guiana) . .-. | $393 / 8$ | 1. 000 | 107 | 171 |
| Uruguay------------------- | 561/2 | 1. 434 | 1, 876 | 3, 001 |
|  | 351/2 | . 895 | 3 | 5 |
|  | 291/2 | . 750 | 9 | 14 |
| Venezuela. | 42 | ' 1. 067 | 290 | 464 |
|  | $393 / 8$ | 1. 000 | 85 | 136 |
|  | 36 | . 914 | 108 | 172 |
|  | 24 | . 609 | 220 | 352 |
| Central America: |  |  |  |  |
| roads). |  |  |  |  |
| Costa Riea | 42 | 1. 067 | 411 | 657 |
| El Salvador----------------- | 36 | . 914 | 385 | 616 |
| Guatemala----------------- | 36 | . 914 | 725 | 1, 160 |
| Honduras------------------1 | 42 | 1. 067 | 489 | 782 |
|  | 36 | . 914 | 286 | 457 |
| Niearagua | 42 | 1. 067 | 235 | 376 |
| Panama. - | 60 | 1. 524 | 150 | 240 |
|  | 36 | . 914 | 105 | 168 |

[^7]Table 25. Foreign Railroad Gages and Mileages-Continued

| Country | Track gage |  | Total length of railroads |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Inches | Meters | Mules | Kılometers |
| Caribbean: Cuba_ |  |  |  |  |
|  | 561/2 | 1. 434 | 2, 666 | 4, 265 |
|  | 36 | . 914 | 57 | 91 |
|  | 30 | . 762 | 68 | 108 |
| Dominican Republic.-------- | 42 | 1. 067 | 86 | 137 |
|  | 30 | . 762 | 62 | 99 |
| Haiti. | 42 | 1. 067 | 112 | 179 |
|  | 30 | . 762 | 75 | 120 |
| Jamaica_ | 561\% | 1. 434 | 208 | 332 |
| Pucrto Rico | 393/8 | 1. 000 | 271 | 433 |
| Trinidad | 561/2 | 1. 434 | 105 | 168 |
| Australasia: |  |  |  |  |
| Australia. | 63 | 1. 600 | 6, 102 | 9, 763 |
|  | 561/2 | 1. 434 | 7, 294 | 11, 830 |
|  | 42 | 1. 067 | 12, 835 | 20,536 |
|  | 30 | . 762 | 114 | 182 |
|  | 24 | . 609 | 30 | 48 |
| New Zealand | 42 | 1. 067 | 3, 530 | 5, 648 |
| Tasmania_ | 42 | 1. 067 | 723 | 1, 156 |
|  |  |  |  |  |
| Formosa. | 42 | 1. 067 | 493 | 788 |
|  | 30 | 4. 762 | 109 | 174 |
| Hawaii | 36 | . 914 | 20 | 32 |
| Hainan | 42 | 1. 067 | 167 | 267 |
| Indoncsia: |  |  |  |  |
| Bornco | 393/8 | 1. 000 | 116 | 185 |
| Jara. | 46 | 1. 168 | 25 | 40 |
|  | 42 | 1. 067 | 2, 665 | 4,364 |
|  | 231/2 | . 600 | 50 | 80 |
| Madurab-------------------- | 42 | 1. 067 | 140 | 224 |
| Stimatria--------------- | 42 | 1. 067 | 846 | 1, 35.3 |
|  | 30 | . 762 | 305 | 488 |
| Philippines---------------------- | 42 | 1. 067 | 655 | 1, 048 |
| Approximate grand totals..- | --- |  | 803, 056 | 1, 283, 157 |

[^8]
## Section VI. SPECIAL DATA

29. Logistics of Prefabricated Buildings

Logistics of prefabricated buildings are given in table 26.
Table 26. Prefabricated Buildings

| Type of building | Size (feet) | Shipping data |  |
| :---: | :---: | :---: | :---: |
|  |  | Number of packages | Measurement tons |
| Quonset building (Great Lakes Steel) - | 40 by 100 | 20 | 9.6 |
| Metal, arch rib (Steelcraft) | 40 by 100 | 20 | 9.7 |
| Metal, rigid frame (Butler) | 40 by 100 | 22 | 12. 2 |
| Advance base hut, steel, northern type (Stecleraft). | 20 by 48 | 11 | 6. |
| Steel, vertical wall: |  |  |  |
| (1) Steelcraft | 20 by 48 | 14 | 8. 3 |
| (2) Great Lakes Steel | 20 by 48 | 11 | 7. 1 |
| Arctic, wood panel, frameless | 20 by 48 | 6 | 26. 0 |
| Barracks, wood frame and plywood | 20 by 48 |  | 40.3 |
| Nissen hut, British. | 16 by 36 |  | 14.0 |
| Do. | 24 by 36 |  | 21.0 |

## 30. Shipping Characteristics of Weapons

The shipping characteristics of certain weapons issued to engincer units are shown in table 27.

## 31. Gases and Gas Cylinders

a. Characteristics. The characteristics of certain gases which are used in industry and in the Army, and which are stored and shipped in a compressed state, are shown in table 28.
b. U.S. and Foreign Cylinders.
(1) In the United Statcs, cylinders for compressed gases are manufactured under various ICC specifications. For details see AR 700-8120-1.
(2) Figure 7 shows the locations of identifying colors on bottletype cylinders as specified in Mil-Std-101-A. Table 29(1) shows the color code which is used under U.S. military standards to identify the contents of cylinders. Table 29(2) shows the color codcs for ccrtain gases in use in four foreign countries. Table 30 shows the characteristics of the cylindcrs used for certain of the more common gases.

T'able a7. Shipping Characleristic: of I' capons

| Nomenclature |
| :--- |


| Rifle, U.S., cal. 130, M | 9. 50 | Wood box. | 10 | 4. 08 | 1. 54 | 1. 08 | 6. 82 | 164. 0 | 17 | 42 | 319 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Riftc, 7.62 mm ., M14 | 8. 7 | Wood box. | 10 | 4. 23 | 1. S | 1. 1 | 8 | 200. 0 | 2 | 35 | 271 |
| Rocket launcher, 3.5-in., M20. | 17.0 | VCI package.- | 4 | 3. 01 | 2. 79 | 1. 33 | 11. 23 | 135. 0 | 28 | 25 | 194 |
| Sniperscope. | 136. 0 | Wood bo | 1 | 3.4 | 1. 5 | 1. 5 | 7. 4 | 188.0 | 185 | 39 | 294 |



Figure 7. Location of colors in botlle-type cylinders.

Table 28. Characteristics of Gases

| Gas | Culor | Octor | Welght when compared to air | Physical state as shipped | Pligsical ellect. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Acetylene. | Nonc. | Gurliclike |  |  |  |
| Annmonia_ | Nonc | Pungent | Lightel- - - ------- - | Dissolved | Anesthetic. |
| Argon. | None | None_ | Lighter------------ Slightly heiviel | Liquid ${ }_{\text {- - - - - - }}$ | Irritant. |
| Cinloon dioxide | Nonse | Fiant | Slighty heaviel'----- Much heavier | Liquid - - - - - - | None. ${ }^{1}$ |
| Chlorinc. - | Grcenish ycllow | Disugreeable_----------------- | Much heavier | Liquid ----.. | Nonc. ${ }^{1}$ |
| Ethylenc oxide.-.------------- | Nolle_------- | Pnngent. - - | Jighter | Liquid ${ }_{\text {Liquid }}$----- | I'ritinnt. |
| Helium | None. | Nonc- | Much lighter------------ | Liçuid_ - - - . - <br> Gas | Tritant. <br> Niouel |
| Hydrogen. | None_ | Nonc- | Much lighter_------- | Gas <br> Gas | None. ${ }^{1}$ <br> Noue ${ }^{1}$ |
| Hydrogen cyanide. | None- | Peach blossom_ | Lighter----------------- | Gas Liquid | None. ${ }^{1}$ <br> Toxic |
| Methyl chloride. - | None. | Ltherlike.-. - | Heavier- | Liguid <br> Liquid | Toxic. <br> Auestletic |
| Nitrogen-.------ | None. | None_- - |  | Gas | Allestlietic. <br> Noue 1 |
| Oxygen------------------------- | None. | None. | Slightly heavier | Gas Gits | None. <br> Noue |
| Petroleum gas-Butanc propane. | Nolle. | Sewel gils------------------- | Heatvier_-------------- | Liquid | None. <br> Anestlotic. |
| ]Refrigerinnt_- | Nonc. | None. |  |  |  |
| Sulphur dioxide. | None.-.---------------- | Rotten cggs--------------- | Much heavier | Liquid | lrritint. |

[^9]Table 29(1). Military Standard 101A-Color Code for Compressed Gas Cylinders and Pipelines

| Title | Top A | Band 13 | Band C | Body |
| :---: | :---: | :---: | :---: | :---: |
| Acetylenc | Yellow . | Ycllow | Yellow | Yellow. |
| Acrolein. | Yellow | Brown | Black | Brown. |
| Aerosol insecticide | Buff | Buff | Buff | Buff. |
| Air, oil pumped | Black | Grcen | Green. | Black. |
| Air, water pumped | Black | Green | Black | 3lack. |
| Ammonia | Brown | Yellow | Orange | Orange. |
| Argon, oil pumped | Gray | White | White | Gray. |
| Argon, water pumped | Gray | White | Gray | Gray. |
| Boron trichloride | Gray | Brown | Gray | Brown. |
| Boron trifluoride | Gray | Brown | Brown | Brown. |
| Bromoacetone. | Brown | Black | Black | Brown. |
| Bromochloromethan | Buff | Gray | Buff | Buff. |
| Bromochloromethanc (fire | Red | Gray | Red | Red. |
| Bromofluoromethane | Orange | White | Gray | Orange. |
| Bromofluoromethane (fire | Red | Whitc | Gray | Red. |
| Butadiene | Yellow | White | Buff | Buff. |
| Carbon dioxide | Gray | Gray | Gray | Gray. |
| Carbon dioxide (fire only) | Red | Red | Red | Red. |
| Carbon monoxicle | Ycllow | Brown | Brown | Brown. |
| Chloroacetone | Black | Brown | Black | Brown. |
| Chlorine | Brown | Brown | Brown | Brown. |
| Chlorine trifluoride | Brown | Grecn | Brown | Brown. |
| Chloropicrin. | Brown | Orangc | Orange | Brown. |
| Cyanogen. | Yellow. | Brown | Yellow | Brown. |
| Cyclopropanc, medical | Orange | Yellow | Blue. | Blue. |
| Cyclopropanc, medical. | Orange | Chromium pl | Chromium pl | Chromium plated. |
| Dibromodifluoromethane. | Bulf | White. | Buff. | Buff. |



| Title | Top A | Band B | Band C | Body |
| :---: | :---: | :---: | :---: | :---: |
| Hydrogen sulfide. | Brown | Yellow | Brown | Brown. |
| Krypton, oil pumped | Gray | Buff | Buff | Gray. |
| Krypton, water pumped. | Gray | Buff | Gray | Gray. |
| Manufactured Gas-(Speciry) Coal, oil, water, producer, etc. | Brown | Yellow. | Yellow. | Yellow. |
| Methane. | Y cllow | White | Yellow | Yellow. |
| Methylamine. | Yellow | Brown | Yellow | Buff. |
| Methyl bromide. | Brown | Black | Brown | Brown. |
| Methyl bromide (fire only) | Red. | Brown | Red. | Red. |
| Methyl chloride. | Ycllow | Brown | Orange. | Orange. |
| Methyl mercaptan | Browh | Yellow. | Yellow. | Brown. |
| Methyl sulfide. | Yellow | Brown_ | Buff | Brown. |
| Methylene chloride | Gray | Blue. | Orange. | Orange. |
| Natural gas.. | Yellow. | Brown | Ycllow | Yellow. |
| Neon, oil pumped | White | Buff. | Gray | Gray. |
| Neon, water pumped. | White_ | 13uff | Buff | Gray. |
| Nickel carbonyl | Yellow | White. | Yellow | Brown. |
| Nitric oxide. | Brown | Buff | Brown | Brown. |
| Nitrogen dioxide. | Brown | Buff | Buff | Brown. |
| Nitrogen, oil pumped | Gray | Black | Gray | Gray. |
| Nitrogen, water pumperl | Gray | Black | Black | Gray. |
| Nitrosyl chloride. | Brown | White | Whitc | Brown. |
| Nitrous oxide | Blue. | Blue. | Bluc | Bluc. |
| Oxygen, medical | White | Green | Creen | Green. |
| Oxygen, aviator's. | Grecn | White | Green. | Green. |
| Oxygen- | Green. | Green | Green. | Green. |
|  | Gray ${ }^{1}$ | White ${ }^{2}$ | Grcen | Green. |


| Petroleum Gas-(Specity) Acetogen, Butane, Butane-Propane, Buteue-1, Cyclopropane, Isobutane, Isobutylene, Neopetine, Propane, etc. | Yellow......-- | Orange...---------- | Yellow.-.--------- | Yellow. |
| :---: | :---: | :---: | :---: | :---: |
| Phenylcurbylamine chtoride. | Brown_ | Gray | Gray | Brown. |
| Phosgene | Brown | Orunge | Brown | Brown. |
| Propylene. | Yellow | Gray | Buff | Buff. |
| Sulfur dioxide | Brown | Gray | Brown | Brown. |
| Sulfur hexafluoride | Gray | White. | Black | Gray. |
| Tetrafluoroethylene, inhibited | Buff | White | White | Buff. |
| Trimethylamine, anhydrous. | Yellow. | Blue. | Orange | Buff. |
| Vinyl bromide. | Buff | Bhue_ | Blue. | Buff. |
| Vinyl chloride | Yellow | Orange | Buff | Buff. |
| Vinyl methyl ether, inhibited | Yellow | Black | Buff | Buff. |
| Xenon, oil pumperl | White | Black | Black | Gray. |
| Xenon, water pumped. | White | Black | Gray | Gray. |

[^10]T'able 29(2). Foreiyn Cylinder Culors

| Gas | England | Austriclla | Japau | Italy | Germany |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Acetylenc. | Purple. | Marooll | Brown. | Orange | Yellow. |
| Carbon dioxide. | black | Brown |  | Vellow. |  |
| Freon 12 |  | Light green |  |  |  |
| Helium | 3rown | Giray |  |  |  |
| Hydrogen | Red | Signal red | Red | Red | Red. |
| Methyl ehloride |  | Light green |  |  |  |
| Nitrogen. | Gray | Dark gray | Purple | Green | Green. |
| Oxygen. | Blatek | Black.- | 131ack. | White | Blue. |
|  |  |  |  |  |  |

Table 30. Characteristics of Cylinders Used for Certain Gases



1 From U.S. Dept. of Commener, National Butwa of Standards, Supplement to Screw-Thread Standards for Federal Services, 1944 (lssued 15 June 1949), Supplement to Handllook H28 (1944)

2 Water-pumped Interıal-nght. Oil-pmoped: Inturnail-leit.

## 32. Processing and Packing

a. General. Processing and packing supplies is a highly important step connected with the shipment or storage of items so that when required they will be in usable conclition. Steps in the above inelude proper cleaning, application of preservatives, paekaging, and crating. Processing materials and their sources are dealt with in SB 38-100.
b. Cleaning. The first step in the procedure is the proper eleaning of the item. No preservative method will protect a part from eorrosion if contaminating residues (deposits foreign to the composition of the part) are present on the surface.
(1) Some causes of corrosion are:
(a) Moisture.
(b) Perspiration from handling.
(c) Residual soldering, welding, or brazing fluxes.
(d) Cutting, cooling, buffing, or grinding compounds.
(e) Dust and ehemieal deposits.
(2) There can be no standard ehoiee or method of cleaning, sinee the eleaner selected and the method used are dependent upon the composition, naturc, and eonstruetion of the part; the nature of contaminants to be removed; the degree of cleanliness required; and the availability of eleaning materials.
(a) The extent of cleaning is determined by the surface to be elcaned, varying from a highly finished part to a rough casting. Naturally, the utmost eare must be taken to remove even fingerprints from highly finished surfaces.
(b) There are four approved types of eleaning materials, plus fingerprint remover or neutralizer. Thesc are:

1. Petroleum solvent (Stoddard).
2. Alkalinc eleaners.
3. Emulsifiable solvents.
4. Vapor degreasers (triehlorethylenc and perchlorethylene).
5. Methanol (fingerprinting ncutralizer).
(c) The parts must be dried after eleaning and beforc applying the preservative. Preferably, drying is donc with eompresscd air or by oven-drying. Drying with a eloth is not recommended and should be used only when compressed air or oven-drying is impracticable.
c. Preservatives. The types of preservatives recommended are given in table 31. Further information may be obtained by referenee to TM 38-230. The applieation of preservatives may be clone by dipping, spraying, brushing, flow-coating, or slushing. Dipping is the preferred method.
d. Methods of Preservation. There arc six basie methods of prescrvation, and a number of submcthods, which are used in the proeessing

Table S1. Prescrvative Compound Chart ${ }^{1}$

| Type | Ireservative | Miltary | Acrontalltical | Ar'my | Navy | Applieation ${ }^{2}$ method and temp. | Description ${ }^{3}$ | Use ${ }^{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| P-1 | 'Thom film preservatuve (hitrd-drying, cold application). <br> 'rhin film preservative | MIL-O1617\%. grade 1. $\mathrm{M} 1 \mathrm{~L}-\mathrm{C}-$ |  |  |  | $\dot{B}_{\text {Brash }}$ dlp), of spray. $40^{\circ} \mathrm{F} .-95^{\circ} \mathrm{F}$. | Dres to a hard film. ThiekHess 0.004 in. (Inix.). Solvententhack. Flish point $100^{\circ} \mathrm{F}$. | On metals under outdoor conditions. Primarily for parts not laving highly fimshed surfices. Not satisfaetory for parts oi equipment damaged by solvent removil. NOT FOR INTRICATE ASSEMIBLIES. Can frequently be used without overwTip. |
| P-3 | (soft filin, colt application). <br>  | 16173, griule 2 |  |  |  | Brushi, tip, or splity. $40^{\circ} \mathrm{r}^{3} .-95^{\circ} \mathrm{k}^{\prime}$ | Nou-lorrel- drying filus. Thickuess 0.002 m. (max). Solvent cintionek. Flash point $100^{\circ} F$ | On metals indoors where easy $\mathbb{C}$ movability is desired. Usually requires overwrap. |
| P-4 | (soft, colt inpplicirtion, water dis. plaeing). | 1617:3, <br> grible 3. |  |  |  | 13:usul, difi, or smay $\cdot 10^{\circ} \mathrm{F} .95^{\circ} \mathrm{F}$. | Non- hiad - drying fim. Tluckness 0.011 in (mine). Solvent cothiack. Flishis bint $100^{\circ} \mathrm{F}$. Also remov. able in loot water. | To displaee water from previously wet surfice. Usible for temporary protection. |
| $P-4$ $P-5$ | Heasy preservatise (lot application, hard filmo. | $\begin{gathered} \text { MIL-C- } \\ \text { 117Uti, } \\ \text { class } 1 . \end{gathered}$ |  |  |  |  | Thick, harel drying, greisy film. | Protection of highly finished pints of simple design for prolonged periods. |
| P-5 P-6 | Mediun preservitive (low, applicition, soft film). <br> Liglit pruservative | MIL-C- <br> 117! 16 , cliss 2. MLL-C- |  |  | $\begin{gathered} \text { MIL-C- } \\ 18487 . \end{gathered}$ | Brush, dip, or surias. Mibsinnmenteres ature of itpplication $190^{\circ} \mathrm{F}$. | Tlaick, medmm firm, greasy filin. | Protection of Inglily finislied parts of relatively simple design for prolonged periods. Requires overwrap. |
| P-7 | (Inot applical.ın, soft film). <br> Medinul preservitive | 11790, class 3. <br> MIL-L- |  |  |  | Brush, dip, or splay. Masimmon temperatilue of ibpplatation $180^{\circ} \mathrm{F}$. | Thom, soft, greaselike film | Protection of highly finished parts of complex design whel can be cleaned. Especially adapted to preserving antifrietion bearmgs. Requires overwiup. |
| - | oil (cold application). | $\begin{gathered} \text { MIL-L- } \\ 3150 \end{gathered}$ |  |  | --- | Blush, dup, or splity. $60^{\circ} \mathrm{F} .-120^{\circ} \mathrm{F}$ | Lube oil witlo added mhibitors. Simular in physicial projuerticsto SAE 30 . Pour point $20^{\circ} \mathrm{F}$. | Protection of oil-lubricated and smil. lar operating parts. Should be supplemented by Metiod IA or II DO NOT USE FOR INTERGAL COMBUSTION EN. NTEES. Must be removed prior to use. |

Table 31. Prescrvative Compound Chart 1-Continued

| Type | Prescrvative | Military | Aeronautical | Army | Navy | Application ${ }^{2}$ method and temp. | Description ${ }^{3}$ | Use ${ }^{4}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| P-8 | Ligbt preservative oil (cold application). | $\begin{aligned} & \text { MII,-L- } \\ & 3503 . \end{aligned}$ |  |  |  | Brush, dip, or spray. $60^{\circ} \mathrm{F} .-120^{\circ} \mathrm{F}$. | Lube oil with added luhibitors. Flash point $300^{\circ} \mathrm{F}$. Pour point $50^{\circ} \mathrm{F}$. Similar in physical properties to SAE 10. | Protection of machine guns and small arms, and operating equipment. Must be removed prior to use in Aretic or in an alrplanc. |
| P-9 | Very light preservative oil (cold applieation). | $\begin{aligned} & \text { MIL-L- } \\ & 644 . \end{aligned}$ |  |  |  | Brush, dip, or spray. $60^{\circ} \mathrm{F},-120^{\circ} \mathrm{F} .$ | Lube oil witb added inhlbitors. Flash point $275^{\circ} \mathrm{F}$. Pour point $70^{\circ} \mathrm{F}$. | Protection of machinc guns and small arins, and operating equipment. Need not be removed from guns prior to use. |
| P-10 | Engıne preservative oil. |  | $\begin{gathered} \text { MIL-C- } \\ 6529 . \end{gathered}$ | MIL-L- <br> 21260, <br> Grade 1, 2 , or 3. | $\begin{aligned} & \text { MIL-1- }- \\ & 21260, \\ & \text { Grade } 1, \\ & 2, \text { or } 3 . \end{aligned}$ | Brush, dip, or spray. $60^{\circ} \mathrm{F} .-120^{\circ} \mathrm{F} .$ | Engıne lubricathg oil with corrosion inlibitors, inclading hydrobromic ackl neutralizers. Pour point MIL-L-21260, grade 1, $10^{\circ} \mathrm{F}$. MIL-L-21260, grade $2,0^{\circ}$ F. MIL $-\mathrm{C}-$ $6529,10^{\circ} \mathrm{F}$. Flosh point: MIL-L-21260, grade 1 , $360^{\circ}$ F. MIL-L-21260, grade $2,390^{\circ} \mathrm{F}$. MIL-C$6529,350^{\circ} \mathrm{F}$. | Protection of internal surface of illternal combustion englnes and other intricate assemblics. |
| P-11 | Preservatlve grease (apillication as required). |  | $\begin{gathered} \text { MII }-\mathrm{G}- \\ 3278 . \end{gathered}$ | $\begin{gathered} \text { MIL-G- } \\ 10924 . \end{gathered}$ | $\begin{gathered} \text { MIL-G- } \\ 16908 . \end{gathered}$ | Brusil. $30^{\circ} \mathrm{F} .-120^{\circ} \mathrm{F} .-$ | Lithium soap grease.------- | Protectlve grease for lubricated bearings. Particularly suitable for equipment which must operate at hoth very low and high temperatures. |
| $\mathrm{P}-12$ | Anti-friction bearing preservative (hot application). |  | $\begin{gathered} \text { MII,-C- } \\ \text { 11796, } \\ \text { Class } 3 . \end{gathered}$ |  |  | Dip. $170^{\circ} \mathrm{F} .-180^{\circ} \mathrm{F}$--- | Medium dark soft petrolatum base material. Flash point $350^{\circ} \mathrm{F}$. | Prescrvatlve grease for lubrleatlng bearings and other semt-complex parts from which it can be removed. Dry lubricant and rust inilibiting |
| P-13 | Waxcmulsion | $\begin{gathered} \text { MIIL-W- } \\ 3688 . \end{gathered}$ |  |  |  | Spray, dip, or wipe. <br> Room temperature. | Aqueous uniform comhination of emulsifying agents, waxes, and resins together with suitable rust inhibitors. Softening point $165^{\circ} \mathrm{F}$. | coating for general wentberproofing when appled to artieles. |


| P-14 | Corrosion preventive for food hathetheng machinery and ('quipment (nontovic). | $\begin{gathered} \text { M1L-C- } \\ 10352 . \end{gathered}$ |  |  |  | Sprity rom temperatilic. | Uniffolm imature of white microcrystalline was, lanolin corrosion inhibitor, 2-Ammo-2-Mcthyl-1-Prophinol, and solvent P-SG61 produces a thin film cusily removed, flash point $100^{\circ} \mathrm{F}$. | Food lamilimg equipment aud machouery. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| P-15 | Hydramlies system preServative oil.s |  |  |  |  |  |  |  |
| P-16 | ${ }^{\text {rohinotropie preserval- }}$ tive oll. | M11.-C5515. |  |  |  |  $120^{\circ} \mathrm{F} .150^{\circ} \mathrm{E}$. | Labu oil wath adeded thickeners and corrosion inhnhi. tors with thisotropic liehavior. Flash point $350^{\circ}$ F . | Protection of intenal and external Sinficees and assenblas where runoff camot be tolerated. Prinnarily for aireraft engines. |
| P-17 | Fistranent laming preservative onl. | M11, 1 (iusis. |  |  |  |  <br> Roon Lempratare | syontletie base lubricatingr on of low volatility wath additive materials to lim. part oxidation stabulity and corrosion protective properthes. Poir point $70^{\circ} \mathrm{F}$. Flash point $365^{\circ} \mathrm{F}$. | Airemat mstruments and efectrouie épinpment. |
| P-18 | Volatile corrosion IIIhibutor. | NL1,-1'- <br> 3420. |  |  |  | Wrap oiv Vés tacahed materind. | Maternals coated or impregmated with a corrosion mhibitor whiel will vola. tilize and whose vipoos prevent rusting of metal sinfaces. | l'wetection of ferrous ructals, :upproved nonferrous metals and approved nonmetablic eomponents during shipment, It:udling, and storage. |

I frarning.-This table is intended to eormehte specefiemtion numbers with certan generally aceepted typers. It does not comote interelangeabilaty, exeept that any compound listed moder MILITARY may be used for any other with the same p number. It may, however, be ased for the selection of alternative preservative conpounds when the speeffe preservatives are not in stock or avialiale from another sourco in sullicient tume to accomplisla the necessary preservation and when there are no specific orders to the contrary. This table is not intended to be used by eontrietors for the selaction of alternate preservative materials unless such selection privilege is meluded in their contritets.
a'These values are typheal. Consult cuan habel for detaled information.
3 These are typicial of the most casily recognized propertics.
A These ate the most common uses. There are many others.
${ }^{3}$ Specifications for lyydraulic preservative onls lave not been listed becanse of varrations in system requirements. Hydraulie preservatives used will be suljuect to approval by the procuring agency.
of parts and equipment. The method used depends upon the nature of the material and equipment and the degree of protection required.
(1) Method I. Preservative coating, with greaseproof wrap when required. Method I is uscd for the proteetion of spare parts and other equipment for shipment and storage, when the nature and construction of the items allow ready application of a corrosive provective compound film by dipping, spraying, flushing, brushing, or fogging.
(2) Method IA. Water-vaporproof inclosure with preservative as required. Method IA is intended to afford adequate proteetion against corrosion caused by water or water vapor, and is applied to parts and equipment where eritical funetioning surfaccs held to close toleranees are involved. There are sixteen submcthods.
(3) Method IB. Strippable compound coating (hot dip). The use of Method IB is limited to parts that have no dccp recesses or complexities of strueture which would prevent complete removal of the plastic eoating, and whose design or eontour is simple. There are two submethods.
(4) Method IC. Waterproof barrier (with preservative as required). Method IC is intendcd to afford adequate proteetion against deterioration eaused by direet entry of water. This is effeeted by a sealed waterproof or water-resistant barrier permitting only water-vapor penetration to the preserved part. There are six submethods.
(5) Method II. Water-vaporproof barrier with desiccant and with preservative when required. Method II is used for items of a highly eritieal nature requiring the highest degree of protection from damage by the effects of water vapor. It is applieable to mechanieal or eleetrieal items including assemblies with functional eomponents whieh, by their nature, eannot be treatcd with a preservativc. It involves inelosing the item(s) or assembly with the rcquired amount of aetivated desieeant within a water-vaporproof barricr. There are six submethods.
(6) Method III. Packaying for mechanical and physical protection only. Items paekaged by Method III should be tied together or inelosed with wrappings, bags, eartons, boxes, or other eontainers as applicablc, to the extent neeessary to provide protection from hazards of eontamination and physical damage eneountcred in gencral handling, storage, and issue.
e. Packaging and Crating.
(1) General. In selecting a container for shipping, the following faetors should be considered:
(a) Suitability of articles to be packed.
(b) Processing used for protection against corrosion.
(c) Availability.
(d) Cubic displacement.
(e) Ease in handling and storing.
(f) Type of load.
(2) Cushioning material. Soft material should be used as cushioning for delieate or fragile items; highly finished surfaces; small projections; protection of moisture-vaporproof and waterproof barriers, ete. However, eushioning material is not used in place of blocking material except in unavoidable cases.
(3) Lumber. The type and thickness of lumber to be used depends on the weight of the articles to be packed. Knots, eross-grain, bark, and other defects sharply reduee the strength of a board. In cutting out lumber, defeets over one-third the board width are eliminated.
(4) Nails.
(a) When nailing lumber together flatwise, nails are driven through and clinched about $1 / 4$ ineh if the combined thickness of lumber is 3 inches or less.
(b) For thiekness over 3 inches, or for nailing a flat to an edge, unelinched nails are used in lengths as long as practicable without splitting the lumber. The minimum nail length to be embedded in the piece holding the point of the nail is two-thirds the nail length for 10d and smaller nails; $1 \not 1 / 2$ inches for $12 d$ and larger nails (Spee. MIL-C-104).
(5) Gross weights. Maximum gross weights for various styles of boxes and crates are given in Table 32.

Table 32. Maximum Gross Weights for Boxes and Crates

| Specification | Type of container | $\begin{aligned} & \text { Masimum } \\ & \text { gross weight, } \end{aligned}$ pounds |
| :---: | :---: | :---: |
| MIL-C-104. | Crate, sheated, wood, nailed | 30,000 |
| MIT-C-132 | Crate, unsheated, wood, nailed: Style A | 1,000 |
|  | Style A-1 | 250 |
|  | Style B. | 2, 500 |
|  | Style C_ | 500 |
| PPP-B-621 | Box, wood, nailed: |  |
|  | Style 1. | ${ }^{1} 50$ |
|  | Styles 2, $2 \frac{1 / 2}{} 3$ | 1,000 |
|  | Styles 4, 5. | 400 |
|  | Style 6. | 50 |
| PPP-B-601 | Box, wood, eleated, plywood | 1,000 |
| MIL-B-107. | Box, wood, wirebound .- | 300 |
| $\underline{\text { PlPP-B-591_-- }}$ | Box, wood, eleated, fiberwood. | 200 |

[^11](6) Design. Figure 6 shows box stylcs. Table 33(1) shows minimum thicknesses of box parts for various styles of box and weights of contents, for domestic shipment and easy or average loads. Tablc 33(2) gives similar data for overseas shipments. For the case of difficult loads, and for other details, see Spec. PPP-B-621. The four groups of woods, as the term is used here, are as follows:

Group I

| Alder, red | Chestnut | Pine (except southern |
| :---: | :---: | :---: |
| Aspen (Popple) | Cucumbertree | yellow) |
| Basswood | Cottonwood | Poplar, yellow |
| Buckeye | Cypress | Redwood |
| Butternut | Fir (true firs) | Spruce |
| Cedar | Magnolia | Willow |
| Group 11 |  |  |
| Douglas-fir Hemlock | Larch, western <br> Pine (southern yellow) | Tamarack |
| Group III |  |  |
| Ash (except white ash) | Maple, soft | Sycamore |
| Cherry | Swectgum | Tupelo |
| Elm, soft |  |  |
| Group IV |  |  |
| Ash, white | Hackberry | Locust |
| Beech | Hickory - | Maple, hard |
| Birch | Pecan | Oak |
| Elm, rock |  |  |



Boxes for domestic shipment, type 1 (easy) and type 2 (average) loads; minimum thiekness of sides, tops, bottoms, and ends, and minimum thickness and width of cleats.

| Welght of conteits |  | Style of box | Groups I and II woods |  |  | Groups III and IV woods |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Excced-lng- | Not ex. ceeding- |  | Minimum thickness of sides, tops, and bottoms 1 | Minimum thickness of ends: | Minimum thickness and width of cleats | Minlmum thickncss of sides, rops, and bottoms ${ }^{1}$ | Minimum thickness of ends | Minimum thickness and width of cleats |
| Pounds | Pounds |  | Inch | Inch | Inches | Inch | Inch | Inches |
|  | 50 |  | 5/16 | 1/2 |  | $1 / 4$ | 1/2 |  |
|  | 50 | 4, 412, 5 | $5 / 16$ | 1/2 | Y/2 by $13 / 4$ | $1 / 4$ | 1/2 | 1/2 by $13 / 1$. |
|  | 50 |  | 5/16 | 3/8 | $3 / 8$ by $11 / 2$ | $1 / 4$ | 5/16 | 5/í by $11 / 2$. |
|  | 50 |  | $1 / 4$ | 1/2 |  | 3/16 | $3 / 8$ |  |
| 50 | 100 | 12 | $3 / 8$ | $3 / 4$ |  | 5/10 | $5 / 8$ |  |
| 50 | 100 | 4, 41/2, 5 | $3 / 8$ | 5/8 | 5/8 by $21 / 4$ | 5/18 | 910 | 9/10 by $13 / 4$. |
| 50 | 100 | 2 | $3 / 8$ | 1/2 | 1/2 by $13 / 4$ | 5/16 | 1/2 | $1 / 2$ by $13 / 4$. |
| 50 | 100 | 26 | $3 / 8$ | $3 / 4$ |  | 5/18 | 5/8 |  |
| 100 | 250 | 4, 41/2, 5 . | $1 / 2$ | 5/8 | 5/8 by $21 / 4$ | 7/16 | 5/8 | 5/8 by $21 / 4$. |
| 100 | 250 | 2, $21 / 2,3$. | $1 / 2$ | 5/8 | 5/8 by $17 / 8$ | 7/16 | 9/10 | 9/6 by $13 / 4$. |
| 250 | . 3400 | 2, $21 / 2$. | $5 / 8$ | $3 / 4$ | $3 / 4$ by $25 / 8$ | 1/2 | 5/8 | 5/8 by $21 / 4$. |

${ }^{1}$ Thacknesses are minimum as stated; however, if parts are surfaced on both sides, but not execeding 100 pounds, if the boxes lave one-picce sides of sawed lumber anit
${ }^{3}$ Weights of contents exceeding 400 pounds stiall be considered type 3 load.

Boxes for overseas shipment, type 1 (easy) and type 2 (average) load—determination of minimum thiekness of sides, tops, bottoms, and ends, and minimum thickness and width of cleats for styles $2,2 \frac{1}{2}, 3,4$, and 5 nailed wood boxes.

| Weight of contents |  | Style of box | Groups I and 1I woods |  |  | Oroups III and IV woods |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Exceed- $\operatorname{lng}-$ | Not ex-cecding- |  | Minimum thickness of sides, tops, and bottoms ${ }^{2}$ | Minimum tbickness of ends ${ }^{2}$ | Minimum thickness and width of cleats ${ }^{1}$ | Minımum thiekness of sides, tops, and bottoms ${ }^{2}$ | Minimum thickness of ends ${ }^{2}$ | Minimum thiekness and width of cleats ${ }^{1}$ |
| Pounds | Pounds |  | Inch | Jnch | Inches | Inch | Inch | Inches |
|  | 50 | 4, 41/2, 5 | 3/2 | 5/8 | 5/8 by $13 / 4$ | 5/10 | 5/8 | 5/8 by $13 / 4$. |
| 50 | 100 | 4, $41 / 2,5$ | $7 / 10$ | $3 / 4$ | $3 / 4$ by $21 / 4$ | 3/8 | 5/8 | $5 / 8$ by $13 / 4$. |
| 100 | 250 | 4, 41/2, 5 | $9 / 10$ | 3/4 | $3 / 4$ by $21 / 4$ | 1/2 | 11/16 | ${ }^{1} 16$ by 214. |
| 100 | 250 | 2, $2 \frac{1}{2}, 3$. | 910 | 5/8 | $5 / 8$ by $21 / 4$ | $1 / 2$ | 5/8 | 5/8 by $21 / 4$. |
| 250 | 400 | 4, 41/2, 5 | 11/10 | 25/32 | 25/32 by $25 / 8$ | $9 / 10$ | $3 / 4$ | $3 / 4$ by $21 / 4$. |
| 250 | 400 | 2, $21 / 2,3$. | 11/18 | 3/4 | $3 / 4$ by $25 / 8$ | 9/16 | 11/10 | 11/1в by $21 / 4$. |
| 400 | 600 | 2, 21/2, 3 | 25/32 | 25/32 | $25 / 32$ by $25 / 8$ | 5/3 | $3 / 4$ | $3 / 4$ by $21 / 4$. |
| 600 | 1,000 | (See table IV) |  |  |  |  |  |  |

1 When the inside depth of a box is 5 inches or iess, end cleats shail not be used Thickness of the ends shall he not less than the combined thickness of the end and cieat as specified for style 4 boxes, or if weigit exceeds 400 pounds, as specified for style 2 boxes. Each slde and end shall be made from one picce except when the end is approxi mately square, a two-piecc end with each end piece of approximately equal thickness
and with the grain of eaeh piece running at right angles to the other may be used. Two-pleee ends shail be nailed together with no fess than two nails ellnched.
${ }^{2}$ If pieces $3 / 8$ ineh or more in thickness are surfaced two sides, the thiekness may be $1 / 32$ inch less than the thickness as determined from the tahle requirements.

## CHAPTER 4 <br> PRISONER-OF-WAR INCLOSURES

## 33. General

FM 27-10 sets forth the general provisions by which our forces will be governed in dealing with enemy personnel. TM 19-500 discusses the treatment and processing of prisoncrs of war and the security measures pertaining to them.

## 34. General Provisions

$a$. Prisoncrs of war must be lodged in buildings or barracks which are healthful, dry, heated, lighted, and protected from fire. Minimum dormitory area and air-space requirements will be the same as for troops at base camps.
b. Prisoners of war will have constantly at their disposal installations conforming to sanitary rules, including the best practicable provisions for baths and showers. They must be enabled to take physical excreise and enjoy the open air. Sexes must be segregated.
$c$. In a theater of operations, prisoners of war will be sheltered in existing facilities when possible. If facilities must be built, they will be of temporary construction. For economy in area and fencing, buildings are best grouped in the center of the inclosure and space between them and deadline fences used for open air and exercise.
d. Prisoner-of-war labor will be used to the maximum in establishing, converting, maintaining, and dismantling sccurity and housing facilities for themselves and their guards. They will not receive wages for work connected with installing, maintaining, or administering the camps.

## 35. Security Provisions

a. Stockade fences (except high masonry walls or impassible terrain features) are temporary barricrs only, to delay escape attempts and the entrance of unauthorized persons or contraband articles long enough to permit guards in towers or perimeter patrols to act.
b. Stockade fences of the following types are considered satisfactory:
(1) A single chain-link woven steel-wire fence (2-inch mesh, 6to 9 -gage wire) not less than 8 feet high, with top $45^{\circ}$ extension arms carrying three strands of barbed wire, and with barbed-wire concertinas anchored to the ground outside the fence.
(2) Two fences of the above type set 8 to 10 feet apart, with barbed-wire concertinas fastened to the top of the outer fence.
c. The delaying effect of the stockade fence is substantially increased by installing a deadline fence (a barbed-wire fence about 3 feet high which prisoners of war are forbidden to cross) about 8 to 10 feet inside the inner stockade fence.
-d. Normally one gateway for one-way vehicular traffic, with a wicket for pedestrians, is adequatc.
$e$. Guard towers with lights are installed to improve observation and to permit enfilading fire along fences and streets and inside the stockade.

## 36. Sequence of Development

a. Prisoner-of-war inclosures arc normally initiated in each army and task force service area, reverting to communications zone control and operation as the army rear boundary is advanced. Information for estimating the number likely to be captured is given in FM 101-10. Priority of other work in forward areas is likcly to restrict construction, and initial prisoner-of-war inclosures will normally consist of existing buildings or tents for shelter, pit-type latrines, expedicnt facilities for cooking and bathing, and a stockade fence. Such facilities should be designed for full development later by prisoner-of-war labor.
b. Table 34 gives basic data on a prisoners-of-war camp for 1,000 men in a temperate climate, using tentage. Table 35 gives similar data for prefabricated or standard frame construction. Table 36 gives the key to coding of the construction standard (the code digit given being the second digit of the four-digit number identifying the type of installation).

Provides inclosure and accommodations for 1,000 Prisoncrs of War. All accommodations in tentagc with earth floors. Bucket type latrines in tentagc.

| Facllity | Size or unit | Basls | $\begin{aligned} & \text { Facillity } \\ & \text { No. } \end{aligned}$ | Number required | Material effort |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | S'T | MT | M 1 H |
| 1 TENTAGE | 57,856 SF | Tent Area. | 703292 | 1 |  |  |  |
| 2 INTERIOR CONSTRUCTION.-- |  |  |  |  | 11 | 14 | 840 |
| Latrine, Bucket Typc, (tent) 12 seats. | $16^{\prime}$ by $32^{\prime}$ | 1 seat/20 men. | $7 \dot{23602}$ | 7 | 11 | 14 | 840 |
| 3 OTHER CONSTRUCTION |  |  |  |  | 182 | 241 | 13, 580 |
| Fence, Security, Type X | 1,000 Ft |  | 872102 | 13 | 104 | 156 | 7, 330 |
| Fence, Security, Type Y | $1,000 \mathrm{Ft}$ - |  | 872103 | 1. 03 | 7 | 9 | 510 |
| Fence, Security, Vehicle \& Man Gate. | Each. |  | 872104 | 8 | 16 | 16 | 1,410 |
| Guard Tower | $16^{\prime}$ by $16^{\prime}$ | $1 /$ cor \& $1 / 600^{\prime}$ fence. | 872301 | 8 | 44 | 44 | 1, 100 |
| Guard Tower | $16^{\prime}$ by $24^{\prime}$ | 1/inclosure | 872401 | 1 | 8 | 12 | 150 |
| Road, 1 Lane, 4' ${ }^{\prime \prime}$ Macadam..-...- | Mile | Installation Rds. | 851002 | 0.04 | 0 | 0 | 80 |
| Sentry Box | $4^{\prime}$ by $4^{\prime}$ | 1/main or comp. gate |  | 4 | 0 | 0 | 0 |
|  | 10,000 Gal. | Effective radius 500'. | 843110 | 1 | 3 | 4 | 240 |
| Site Preparation---------------------- | Acre | 100' outside perim.--- | 932000 | 23 | 0 | 0 | 2, 760 |
| Total.-- |  |  |  |  | 193 | 255 | 14, 420 |

P.W. CAMP, 1,000 MAN, TEMPERATE CLIMATE, STD 3, NEW CONST, PREFAB or STD FRAME (Site and Utility Dwg. 70-32).

Provides inclosure and accommodations for 1,000 Prisoners of War. Bathhouse, kitchen and latrine in buildings; all other accommodations in tentage. Concrete floors: buildings and tentage $2^{\prime \prime}$, except Generator Bldg. $4^{\prime \prime}$. Bucket type latrines.

Engineer Services Required:
Water-10,000 GPD.
Drainage-Open Ditch.
Electrical Connected Load-65.9 KW.

| Facility |  | Slze or unit | Basls | $\begin{gathered} \text { FacIIIty } \\ \text { No. } \end{gathered}$ | Number required | Material effort |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | ST |  |  |  | MT | MH |
|  | PREFAB BLDGS COMPLETE... |  | 8,700 SF | Phases 1 \& 2. | 703201 | 1 | 39 | 113 | 950 |
|  | Frame, Roof, \& Foundation | Phase 1 |  | 703202 | 1 | 32 | 73 | 440 |
|  | Cladding- | Phase 2 |  | 703203 | 1 | 7 | 40 | 510 |
| 2 | STD FRAME BLDGS COMPLETE. | 8,700 SF | Phases 1 \& 2 | 703205 | 1 | 77 | 149 | 3,330 |
|  | Frame, Roof, \& Foundation - . .-- |  | Phase 1 | 703206 | 1 | 52 | 115 | 2,670 |
|  | Cladding- |  | Phase 2 | 703207 | 1 | 25 | 34 | 660 |
| 4 | TENTAGE | 49,152 SF | Tent AreaPhase 3- | 703292 | 1 |  | -- |  |
|  | FLOORS |  |  |  |  | 109 | 109 | 1,280 |
|  | Concrete, $2^{\prime \prime}$----------------------- | 1,000 SF |  | 342452 | 57. 5 | 108 | 108 | 1,250 |
|  | Concrete, $4^{\prime \prime}$-------------------- | 1,000 SF |  | 342454 | . 4 | 1 | 1 | 30 |

Table 95-Continued

| Faclility | Size or uuit | Buss | $\begin{aligned} & \text { Facility } \\ & \text { No. } \end{aligned}$ | Numberrecturred | Mitterial effort |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | ST | MT | MII |
| 5 INTERIOR CONSTRUCTION. |  |  |  |  | 45 | 91 | 3,680 |
| Bathhouse, 24 Shower Heads | $20^{\prime}$ by $50^{\prime}$ | 1 sh hd/24 menn-- | 723401 | 2 | 14 | 28 | 1, 240 |
| Generator Bldg., 3-30 K W. Units_ | $20^{\prime}$ by $20^{\prime}$ | 1/installation | 811203 | 1 | 11 | 25 | 260 |
| Kitchen, 500 Man-------------- | $40^{\prime}$ by $60^{\prime}$ | $3 \mathrm{SF} / \mathrm{man}$ | 726201 | 2 | 14 | 28 | 1, 560 |
| Latrine, Bucket Type, 12 Seats .-- | $10^{\prime}$ by $30^{\prime}$ | 1 seat/20 men. | 723601 | 5 | 6 | 10 | 620 |
| 6 OTHER CONSTRUCTION |  |  |  |  | 263 | 408 | 21, 630 |
| Fence, Security, Type W-.-.-.--- | 1,000 Ft. |  | 872101 | 1. 97 | 18 | 28 | 1,540 |
| Fence, Security, Type X | $1,000 \mathrm{Ft}$. |  | 872102 | 11.0 | 88 | 132 | 6, 160 |
| Fence, Security, Type Y . .-...-- | $1,000 \mathrm{Ft}$ |  | 872103 | 1. 03 | 7 | 9 | 510 |
| Fence, Security, Vehicle, \& Man Gate. | Each_- |  | 872104 | 8 | 16 | 16 | 1, 410 |
| Guard Tower. | $16^{\prime}$ by $16^{\prime}$ | $1 /$ cor \& $1 / 600^{\prime}$ fence | 872301 | 8 | 44 | 44 | 1, 100 |
| Guard Tower | $16^{\prime}$ by $24^{\prime}$ | 1/inclosure | 872401 | 1 | 8 | 12 | 150 |
| Road, 1 Lane, $4^{\prime \prime}$ Macadam | Mite. | Installation Rds. | 851002 | 0.04 | 0 | 0 | 80 |
| Sentry Box-------------- | $4^{\prime}$ by $4^{\prime}$ | 1/main or comp gate |  | 4 | 0 | 0 | 0 |
| Sump, Fire Protection---------- | 10,000 Gal | Effective radius $500^{\prime}$ - | 843110 | 1 | 3 | 4 | 240 |
| Utilities: | Util Dwg | $10 \mathrm{GPD} / \mathrm{man}$. | 703210 | 1 | 11 | 17 | 1,780 |
| Drainage-------- | Util Dwg. | Waste water ditch. | 703211 | 1 | 1 | 1 | 190 |
| Electric Distribution-------- | Util Dwg- | Light | 703212 | 1 | 67 | 145 | 5, 710 |
| Site Preparation----------------- | Acre | $100^{\prime}$ outside perimeter | 932000 | 23 | 0 | 0 | 2,760 |



Table 36. Coding of Construction Standards

| Code digit | Standard of construction |  |
| :---: | :---: | :---: |
| 1 | 1 | TOE tents; no engineer materials or effort involved. |
| 2 | 2 | Class IV tents pitched by using troops; engineer effort for roads and site preparation. |
| 3 | 3 | Buildings with floors for administration, bathhouses, infirmaries, storehouses, and kitchens. Class IV tents with floors for housing and with earth floors for all other purposes. Roads within the installations are stabilized with local materials. Water piped from central storage tank to infirmaries, bathhouses, and kitchens. Electric distribution to buildings. Pit type latrines. |
| 4 | 4 | Buildings with floors for all purposes except housing; Class IV tents with floors and wood frames for housing; roads within the installations are stabilized with local materials; water piped from central storage tank to infirmaries, bathhouses, kitchens, and camp exchange; electric distribution to buildings and tent housing. Pit type latrines. |
| 5 | 5 | Buildings with floors for all purposes. Roads, water supply, and latrines are the same as type 4 above; electric distribution to all buildings. |
| 6 | 6 | Buildings with floors for all purposes; latrines equipped with untreated sewage carried 1,000 feet beyond the confines of the camp; bituminous surfacing of roads within the installations; water piped from central storage tank to infirmary, bathhouses, latrines, kitchens, and camp exchange; electric distribution to all buildings. |

# CHAPTER 5 <br> FORTIFICATIONS AND CAMOUFLAGE 

## Section I. GENERAL

## 37. General

Priority of work and data on clearing, on hand excavating for earthworks, and on minefields and barbed-wire entanglements are given in FM's $5-15,5-34$, and $101-10$. Land-mine warfare is covered in FM $20-32$. FM 101-10 includes estimating data for roadblocks and other antimechanized defense measures, as well as data on fordable depths of water and carrying capacity of ice. Permanent bombresistant structures are covered in TM 5-310. FM 5-20, 5-21, FM 5-22, and AFM 200-43 deal with camouflage.

## 38. Frontages Held by Units in Defense

Average frontages normally assigned to infantry or engineer units in defensive missions are given in table 37.

Table 37. Defense Frontages (in yards) SITUATION

| Unit | Branch | Non-nuclear | Actlve nuclear |
| :---: | :---: | :---: | :---: |
| Battle group_- | Infantry..... | $2,500-4,500$ | $4,000-6,000$ (no mobility) ; 7,000 <br> (calculated risk) ; 9,000 (motor- <br> ized or mechanized). |

ALL SITUATIONS

| Riftc company | Infantry | 1 platoon | 2 platoons | 3 platoons | 4 platoons |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Close terrain... | Occupies | 300 | 600 | 900 | 1, 200 |
|  | Occupies and covers. | 500 | 1,000 | 1,500 | 2, 000 |
| Open terrain. .- | Occupies. | 450 | 900 | 1, 400 | 1, 800 |
|  | Occupies and covers..-- | 800 | 1,600 | 2, 400 | 3, 000 |

## Section II. COVER AND SHELTER

## 39. General

a. Requirements. Shelters are constructed primarily to protect troops from enemy action and the weather. They are not fighting emplacements but are often included in fighting positions. Shelters should be sited on reverse slopes, in woods, or in some form of natural defilade such as ravines, valleys, or depressions. All shelters must be camouflaged or concealed.
b. Types. Shelters are divided into two groups according to their type of construction-hasty or delibcrate.
(1) Hasty shelters are normally constructed of local, expedient materials by combat troops, primarily for protection from inclement weather when on short halts and bivouacs.
(2) Deliberate shelters are constructed by supporting units in rear of frontlines for protection from artillery fire, strafing, bombing, and the weather.
(3) Shelters, whether hasty or deliberate, are further divided into three general types-
(a) Surface shelters built aboveground where ground conditions prohibit excavation.
(b) Cut-and-cover shelters partially or wholly dug into the ground and backfilled and covered with soil.
(c) Cave shelters dug laterally into reverse slopes or tumeled into flat ground.

## 40. Protection Against Conventional Weapons

a. Table 38 shows the thicknesses of various materials required to protect against single direct hits by direct-fire weapons.
$b$. Table 39 shows the thicknesses of various materials required to protect against projectiles and bombs exploding at a distance of 50 feet.



Protective theknessus given are for a single shot only (exeept i). Where direct-fite weapons are able to get 5 or 6 hits in the same area, the required protectlve thlekness is approximately twice that indicated.

Table 89. Material Thicknesses Needed for Protection Against Projectiles and Bombs Exploding 50 Feet Away

| Hlgh-explosive shells and rockets |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Material |  |

${ }^{1}$ Figures based on dry materlal. If wet material, double figures.
${ }^{2}$ Figures glven to nearest $3 \mathbf{5}$ foot.

## 41. Ice and Snow: Classification

The following terms and criteria are used to describe snow conditions.
a. Grain Nature.
(1) New snow (original crystal forms).
(2) Old snow (granular).
(a) Fine-grained like table salt.
(b) Coarse-grained like coarse sand.
b. Hardness. (Use mitten or glove.)
(1) Soft (mitten tip or four fingers).
(2) Medium hard (mitten thumb or one finger). ${ }^{1}$
(3) Hard (pencil). ${ }^{1}$
(4) Very hard (knife). ${ }^{1}$
c. Wetness. (Use mittens or gloves.)
(1) Dry (snowball cannot be made).
(2) Moist (does not contain water, but snowball can be made).
(3) Wet (liquid water can be pressed out).
(4) Slushy (mixture of snow and liquid water).

[^12]d. Surface and Profile Conditions. When appropriate, surface and profile conditions may be described in connection with the above classification. For examplc; in describing a snow profile the thickness of visually distinguisbable layers and their sequence can be measured and the snow type of each layer indicated by the above classification. Drifted snow of granule form is always considered as old snow even if freshly deposited.
e. Examples.
(1) New snow, dry and medium hard.
(2) Fine-grained old snow, moist and hard.
(3) Thirty inches of fine-grained old snow, dry and very hard, covered by six inches of ncw snow, soft and dry.
(4) Six-inch crust of fine-grained old snow over six inches of drifted snow, medium hard and dry.
(5) Six inches of coarse-grained old snow, soft and slushy.

## 42. Ice and Snow Cover

Minimum thicknesses of snow and ice for protection against smallarms fire are as follows:

New snow, 13 feet.
Tamped snow, 8 to 10 feet.
Frozen snow, 6.5 feet.
Ice, 3.25 feet.
Ice concrete, 1 to 2 feet.

## 43. Ice Concrete

Ice concrete is a dense frozen mixture of sand and water, or sand with gravel and crushed rock and water. At lcast 10 percent of the mixture should be sand and only enough water should be added to the mixture to make it slightly liquid. A shect of this material, 4 inches thick, will freeze solid in 4 to 6 hours at $-13^{\circ} \mathrm{F}$. In fortification construction it is used for overhead cover, parapets, brcastworks, or sandbag filler.

## 44. Protection Against Nuclear Weapons

See FM 101-31, FM 101-31A, TM 5-311, TM 23-200, DA Pam 39-1, and DA Pam 39-3.

## Section III. OBSTACLES

## 45. Planning and Construction of Obstacles

Normal obstacle planning accomplished in divisional and larger units is summarized in table 40 . Table 41 is an obstacle planning checklist for unit engineers, and table 42 shows obstacle construction data.

Table 40. Obstacle Planning Responsibilities

| Command | Pertinent points of commander's plans |
| :---: | :---: |
| Army | (1) Broad barrier plan for army area, including key bands. <br> (2) Assignment of tasks to subordinate units. Covering forces construct covering barriers, and security forces on open flanks erect flank barriers. Army and corps troops install rear-area and flank barriers. <br> (3) Limitations on use of obstacles in any particular area to insure coordination with general plans. <br> (4) Emphasis on need for sccrecy. Precautions must be taken to safeguard charts and maintain security of barrier plan. Broad plan should not go below division. |
| Corps | (1) Detailed barrier plan for corps area, made from map study, covering: <br> (a) Location of natural and artificial barriers, including major minefields; <br> (b) Location of lanes to be left open for counter-attack plans and supply. <br> (2) Assignment of tasks to subordinate units including division and corps troops. <br> (3) Close coordination of division plans. <br> (4) Detailed siting of corps flank barriers. <br> (5) Maps or overlays showing plan in enough detail so lower units will know exactly which barrier lines are to be installed or reinforced. |
| Division... | Based on corps master plan: <br> (1) Plan of bands or zones of obstacles and purpose each is to serve. <br> (2) Timetable and priority of construction. <br> (3) Demolition orders. <br> (4) Routes to be kept open in accordance with tactical plan. <br> (5) Need for secrecy. Detailed plan should not be in hands of front-line units. <br> (6) Limitations on use of chemical agents. <br> (7) Assignment of troops and equipment for construction and defense. |

Table 42. Obstacle Construction Data


## 46. Minefields

a. The various types of minefields are as follows:
(1) Protective minefields, used for the close-in protection of small units in forward combat areas and units or installations in rear areas if infiltration, raiding, or sabotage is a threat.
(2) Defensive minefields, used as an element in the defense of organized and occupied tactical localities within a battle position.
(3) Barrier minefields, used to block an enemy attack in certain areas and to canalize his advance into other selected areas.
(4) Nuisance minefields, used to delay and disorganize the enemy and hinder his use of a certain area or route.
(5) Phony minefields, used to make the enemy think that an area has been mined.
$b$. Logistical data on antitank and antipersonnel mines are shown in table 43 . Table 44 shows data on minefield clearing with explosive devices. The weights and explosive contents of certain American and foreign mines are given in paragraph 210. For further details, see FM 5-25, FM 20-32, and TM 9-1946.

Table 43. Logistical Mine Data Table
Note: Figures in parentheses indicate maximum load w/in 100 percent overhcad capability \&/or maximum volume of cargo space

| Mine mudel \& type | $\begin{gathered} \text { Welglit } \\ \text { (bly.) per } \\ \text { mine } \end{gathered}$ | Mlue puckaging data |  |  |  |  | Capacity of indicated army velicicles |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Number of nullies, etc., ber crate |  | Craft dimenslons (in.) |  |  | M-35 $21 / 2$-ton cargo truck (cargo spaee: 147 by 58 by co in.) |  |  |  |  |
|  |  |  |  | Lellgth | Widti | Height | $\left\lvert\, \begin{gathered} \text { Number of } \\ \text { crates } \end{gathered}\right.$ | How earried | $\begin{array}{\|c} \text { Number of } \\ \text { types of } \\ \text { crates } \end{array}$ | $\left\|\begin{array}{c} \text { Total num- } \\ \text { ber mines } \end{array}\right\|$ | $\begin{gathered} \text { Total } \\ \text { weight } \\ \text { (tons) } \end{gathered}$ |
| M-7 AV-------- | 5. 0 | a. 8 , w/fuzes..-- | 56 | 19.25 | 11 | 8. 25 | $\begin{gathered} 90 \\ (178) \end{gathered}$ | Flat-.---- | $\begin{gathered} 2 \\ (4) \end{gathered}$ | $\begin{gathered} 720 \\ (1,424) \end{gathered}$ | $\begin{gathered} 2.52 \\ (4.98) \end{gathered}$ |
|  |  | b. 12, w/fuzes.-- | 71.5 | 23. 5 | 11. 75 | 9.5 | $\begin{gathered} 70 \\ (140) \end{gathered}$ | Flat | $\begin{gathered} 2 \\ (4) \end{gathered}$ | $\begin{gathered} 840 \\ (1,680) \end{gathered}$ | $\underset{(5)}{2.5}$ |
| M-6 AT-------- | 20.0 | a. uncrated mines. | 13.13 in. diam.-- |  | --- | 3. 25 |  | Flat | 4 | $\begin{gathered} 250 \\ (264) \end{gathered}$ | $\begin{gathered} 2.5 \\ (2.64) \end{gathered}$ |
|  |  | b. 1, w/fuze \& activ. | 31 | 13.5 | 13.5 | 3. 75 | $\begin{gathered} 162 \\ (322) \end{gathered}$ | $\begin{array}{r} \text { On end } \\ \text { (Ilat) } \end{array}$ | $\begin{gathered} 1 \\ (6) \end{gathered}$ | $\begin{gathered} 162 \\ (322) \end{gathered}$ | $\begin{gathered} 2.51 \\ (4.99) \end{gathered}$ |
|  |  | c. 2, w/fuzes \& activ. | 60 | 18. 13 | 16 | 9. 75 | $\begin{gathered} 84 \\ (160) \end{gathered}$ | Flat.- | $\begin{gathered} 2 \\ (4) \end{gathered}$ | $\begin{gathered} 168 \\ (320) \end{gathered}$ | $\begin{array}{r} 2.52 \\ (4.8) \end{array}$ |
| M-15...-.-.-.- | 30.0 | a. uncrated mines. | ----- | 13.13 in. | diam- - | 5 | ----- | Flat (flat, 11 on end). | $\begin{gathered} 3- \\ (3) \end{gathered}$ | $\begin{gathered} 166 \\ (209) \end{gathered}$ | $\begin{gathered} \text { 2. } 49 \\ (3.13) \end{gathered}$ |
|  |  | b. 1, w/fuze \& activ. | 49 | 18 | 15. 13 | 7. 5 | $\begin{gathered} 103 \\ (200) \end{gathered}$ | Flat. | $\begin{gathered} 3 \\ (5) \end{gathered}$ | $\begin{gathered} 103 \\ (200) \end{gathered}$ | $\begin{array}{r} 2.53 \\ (4.9) \end{array}$ |

Table 43. Logistical Mine Data Table-Continued

| Mine model \& typc | Weight(lb.) per mine | Mine packaging data |  |  |  |  | Capacity of Indicated army vehicles |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Number of mines, etc., | Wt (lb.) per crate | Cralt dimensions (in.) |  |  | M-35 21/2-ton cargo truck (cargo space: 147 by 88 by 60 in .) |  |  |  |  |
|  |  |  |  | Length | Width | Helght | $\underset{\text { crates }}{\text { Number of }}$ | How carried | Number of types of crates | Total number mines | Total welght (tons) |
| M-19 AT-...-.- | 28. 0 | 2, w/fuzes \& activ. | 80 | 16. 25 | 10. 5 | 16 | $\begin{gathered} 63 \\ (125) \end{gathered}$ | On end (on side) | $\begin{gathered} 1 \\ (3) \end{gathered}$ | $\begin{gathered} 126 \\ (250) \end{gathered}$ | $\begin{aligned} & 2.52 \\ & (5) \end{aligned}$ |
| T29 AT | 15. 0 | $\begin{aligned} & \text { 2, w/T-1200 } \\ & \text { fuzes. } \end{aligned}$ | 50.3 | 26.5 | 11 | 7. 33 | $\begin{gathered} 100 \\ (198) \end{gathered}$ | On end (flat). | $\begin{gathered} 1 \\ (5) \end{gathered}$ | $\begin{gathered} 200 \\ (396) \end{gathered}$ | $\begin{gathered} 2.51 \\ (4.97) \end{gathered}$ |
| M-2 AP.- | 5.0 | 6, w/fuzes \& wire. | 50 | 15 | 10. 25 | 9. 5 | $\begin{gathered} 100 \\ (200) \end{gathered}$ | Flat.-.- | $\begin{gathered} 2 \\ (3) \end{gathered}$ | $\begin{gathered} 600 \\ (1,200) \end{gathered}$ | 2. 5 <br> (5) |
| M-3 AP.-.-..- | 9.6 | 6, w/fuzes \& wire. | 72 | 18 | 8. 75 | 9.5 | $\begin{gathered} 70 \\ (138) \end{gathered}$ | Flat--- | $\begin{array}{r} 2- \\ (2+) \end{array}$ | $\begin{aligned} & 420 \\ & (828) \end{aligned}$ | $\begin{gathered} 2.52 \\ (4.96) \end{gathered}$ |
| M-16 AP...... | 8.0 | 4, w/fuzes \& wire. | 45 | 15. 75 | 10. 13 | 8. 5 | $\begin{gathered} 112 \\ (222) \end{gathered}$ | Flat... | $\begin{gathered} 2 \\ (4) \end{gathered}$ | $\begin{gathered} 448 \\ (888) \end{gathered}$ | $\begin{gathered} 2.52 \\ (4.99) \end{gathered}$ |
| M-18 AP.-...-- | 2.5 | a. 6 (M-68 Kit) - | 33. 1 | 20 | 11.5 | 9.75 | $\begin{gathered} 151 \\ (294) \end{gathered}$ | Flat. | $\begin{gathered} 4 \\ (6) \end{gathered}$ | $\begin{gathered} 905 \\ (1,764) \end{gathered}$ | $\begin{gathered} 2.49 \\ (4.87) \end{gathered}$ |
|  |  | b. 10 (M-69 Kit). | 45 | 14. 25 | 15 | 17. 25 | $\begin{gathered} 112 \\ (162) \end{gathered}$ | Flat.-.- | $\begin{gathered} 2+ \\ (3) \end{gathered}$ | $\begin{gathered} 1,120 \\ (1,620) \end{gathered}$ | $\begin{gathered} 2.52 \\ (3.64) \end{gathered}$ |


| M-14 AP----- | 0.2 | 90, w/dets. \& wrenches. | 44 | 19 | 18 | 8. 75 | $\begin{gathered} 114 \\ (227) \end{gathered}$ | Flat (on end). | $\begin{aligned} & 4 \\ & 3 \end{aligned}$ | $\left\|\begin{array}{r} 10,260 \\ (20,430) \end{array}\right\|$ | $\begin{gathered} 2.5 \\ (4.99) \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| E-5 chem------ | 24. 7 | 3, w/fuzes \& activ. | $\begin{aligned} & \text { a. } 110 \\ & (1 \\ & \text { drum) } \end{aligned}$ | 17.5 in . diam. <br> (standard shipping drum). |  | 22 | $\begin{gathered} 46 \\ (80) \end{gathered}$ | $\begin{aligned} & \text { On side (on } \\ & \text { end). } \end{aligned}$ | $\begin{gathered} 2 \\ (2) \end{gathered}$ | $\begin{gathered} 138 \\ (240) \end{gathered}$ | $\begin{array}{r} 2.53 \\ (4.4) \end{array}$ |
|  |  |  | b. <br> 1,840 <br> (pal- <br> let of <br> 16 <br> drums) | 52 | 46 | 48 | 3 pallets. | Flat.------ | 1 | 144 | 2. 76 |
| $\begin{aligned} & \text { M-48 Para- } \\ & \text { chute Flare. } \end{aligned}$ | 5. 0 | 4, w/fuzes \& wire. | 41.0 | 14.7 | 13. 13 | 11 | $\begin{gathered} 122 \\ (244) \end{gathered}$ | Flat ------- | $\begin{gathered} 2+ \\ (4+) \end{gathered}$ | $\begin{gathered} 488 \\ (976) \end{gathered}$ | $\begin{aligned} & 2.5 \\ & (5) \end{aligned}$ |
| M-49 Static Flare. | 1. 4 | a. 16, w/fuzes \& wire. | 44.9 | 21. 25 | 14. 5 | 11 | $\begin{gathered} 111 \\ (180) \end{gathered}$ | Flat.------ | $3+$ <br> (5) | $\begin{gathered} 1,776 \\ (2,880) \end{gathered}$ | $\begin{gathered} \text { 2. } 49 \\ (4.04) \end{gathered}$ |
|  |  | b. 25, w/fuzes \& wire. | 59 | 21. 25 | 14.5 | 11 | $\begin{gathered} 84 \\ (170) \end{gathered}$ | Flat.-..--- | 3- <br> (5) | $\begin{gathered} 2,100 \\ (4,250) \end{gathered}$ | $\begin{aligned} & \text { 2. } 47 \\ & (5) \end{aligned}$ |

Table 43. Logistical Mine Data Table-Continued
$\stackrel{\rightharpoonup}{\boldsymbol{\omega}}$

| Mine model \& type | M-105 11/2-ton trailer (cargo space: 133 by 87 by 71 in .) |  |  |  |  | M-47 $21 / 2$-ton dump truck (cargo space: 108 by 70 by 15 in .) (Volumc is determining factor) |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{array}{\|} \text { Number of } \\ \text { crates } \end{array}$ | How carried | Number of tiers of crates | $\left\lvert\, \begin{gathered} \text { Total num- } \\ \text { ber of } \\ \text { mines } \end{gathered}\right.$ | Total weight (tons) | Determine number of crates | Capacity how carried | Number of tiers of crates | Total number mincs | Total welgit (tons) |
| M-7 AV. | $\begin{gathered} 56 \\ (110) \end{gathered}$ | Flat.---------- | $\begin{gathered} 2 \\ (3) \end{gathered}$ | $\begin{gathered} 448 \\ (880) \end{gathered}$ | $\begin{gathered} 1.56 \\ (3.08) \end{gathered}$ | 72--------- | On end.---- | 1 | 576 | 2. 01 |
|  | $\begin{gathered} 41 \\ (85) \end{gathered}$ | Flat (on end)--- | $\begin{gathered} 2 \\ (1) \end{gathered}$ | $\begin{gathered} 492 \\ (1,020) \end{gathered}$ | $\begin{gathered} 1.46 \\ (3.02) \end{gathered}$ | 63--------- | On end....- | 1 | 756 | 2. 25 |
| M-6 AT |  | Flat (on edge).-: | $\begin{gathered} 3 \\ (2) \end{gathered}$ | $\begin{gathered} 150 \\ (300) \end{gathered}$ | $\begin{aligned} & 1.5 \\ & (3) \end{aligned}$ | ----------- | On edge.-.- | 1 | 165 | 1. 65 |
|  | $\begin{gathered} 96 \\ (195) \end{gathered}$ | Flat_--------- | $\begin{gathered} 2 \\ (4) \end{gathered}$ | $\begin{array}{r} 96 \\ (195) \end{array}$ | $\begin{gathered} 1.48 \\ (3.02) \end{gathered}$ | 140------- | On end..-. | 1 | 140 | 2. 17 |
|  | $\begin{gathered} 50 \\ (100) \end{gathered}$ | Flat.-.-.-...-- | $\begin{gathered} 2 \\ (4-) \end{gathered}$ | $\begin{gathered} 100 \\ (200) \end{gathered}$ | $\begin{aligned} & 1.5 \\ & (3) \end{aligned}$ | 42-------- | On end.....- | 1 | 84 | 1. 26 |
| M-15-..------ |  | Flat (on edge)... | $\begin{gathered} 3 \\ (2) \end{gathered}$ | $\begin{gathered} 100 \\ (200) \end{gathered}$ | ${ }_{(3)}^{1.5}$ |  | $\begin{aligned} & \text { On edge } \\ & \text { (or flat). } \end{aligned}$ | $\begin{gathered} 1 \\ (3) \end{gathered}$ | 105 | 1. 57 |
|  | $\begin{gathered} 51 \\ (122) \end{gathered}$ | Flat.---------- | 2 | $\begin{gathered} 61 \\ (122) \end{gathered}$ | $\begin{gathered} 1.49 \\ (2.98) \end{gathered}$ | 56.-------- | On end....- | 1 | 56 | 1. 37 |
| M-19 AT | $\begin{gathered} 37 \\ (75) \end{gathered}$ | Flat.--------- | $\begin{aligned} & 1- \\ & 2 \end{aligned}$ | $\begin{array}{r} 74 \\ (150) \end{array}$ | $\begin{aligned} & 1.48 \\ & (3) \end{aligned}$ | 40--------- | On end.--- | 1 | 80 | 1. 6 |
| T29 AT | $\begin{gathered} 59 \\ (119) \end{gathered}$ | Flat.--------- | $\begin{gathered} 2 \\ (4-) \end{gathered}$ | $\begin{gathered} 118 \\ (238) \end{gathered}$ | $\begin{gathered} \text { 1. } 49 \\ (2.99) \end{gathered}$ | 81-------- | On end.-- | 1 | 162 | 2. 03 |



| Item | M3A1 | Cable, detonating, mine-elearing, AP, M1 | Bangalore torpedo |
| :---: | :---: | :---: | :---: |
| Purpose. | Breach AT minefield | Clear narrow lane in AP minefield. | (1). |
| Length. | 400 ft | 170 ft | 50 ft . |
| Weight | 9,000 lb - | 63 lb . | 168 lb . |
| Weight of explosive. | 4,480 lb_ | 46 lb | 85 lb. |
| Metal used in case | Aluminum. | Aluminum. | Aluminum. |
| Crater produced: |  |  |  |
| Length.... | 320 ft |  | 56 ft . |
| Width. | 4-12 ft. or more |  | ${ }^{3}$ ). |
| Depth | $2-4 \mathrm{ft}$. or more |  | ${ }^{3}$ ). |
| Usual width of mine clearance accomplished. | $10-15 \mathrm{ft}_{\text {- }}$ | 8 ft . or less ${ }^{4}$ | 10 ft . or less. ${ }^{1}$ |

1 The primary purpose of the bangalore torpedo is to clear a path through wire. It will destroy or detonate most AP and A'T mines within 5 ft . of it.
${ }^{2}$ No elearly defined crater. Surface soll disturbed.
${ }^{3}$ Shallow.
4 Mines directly under the eable will be destroyed or detonated. Pressure-type mines within 5 ft . of it may or may not be detonated.
47. Wire Entanglements

Quantities and estimating data for barbed-wire obstacles are given in FM 101-10 and FM 5-34. Fundamental principles used in locating them are summarized in table 45 . Table 46 shows quantities and truckloads required per thousand yards of the various barbed-wire entanglements.

Table 45. Barbed-Wire Entanglement Principles

| Type according to mission | Location | Deptb | Siting requirements | Gaps |
| :---: | :---: | :---: | :---: | :---: |
| Tactieal | Along friendly side of final proteetive line. Extend across front of a position but are not neeessarily continuous. | 1 belt minimum. | (1) Covered by fire. <br> (2) Under observation and protected by antipersonnel mines and warning devices. ${ }^{1}$ | Leave gaps during erection to: <br> (1) Provide passage for patrols or working partics. <br> (2) Permit advance of attaeking or eounterattacking elements. |
| Proteetive...- | Close enough to defense area for day and night observation and far enough away to keep enemy beyond normal hand grenade range. |  | layouts and easily disclosed positions. <br> (4) Coneealed from ground and air observation wherever possible by ineorporation of natural features sueh as hedges, woods, paths, or fenec lines. <br> (5) Coordinated with other elements of the defense. <br> (6) Use in sufficient quantity. |  |
| Supplementary | In regular lines in front of tactical wire and between mortar target areas; and to eonnect platoon and eompany defense areas. | 1 belt. | Added when time permits, to conceal exact location and direction of tactical wire. | - |

[^13]T'able 46. Wire Loads.

| Type | Tons | Measure-menttons 1 | Truckloads |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | 3/4-ton | 21,8-ton |
| Double apron, 4 and 2 pace | 5 | 6. 4 | 7 | 2 |
| Double apron, 6 and 3 pace | 3. 5 | 4. 5 | 5 | 2 |
| High wire (less guy wires) | 6 | 7. 6 | 8 | 3 |
| Low wire, 4 and 2 pace. | 3. 75 | 4. 75 | 5 | 2 |
| 4-strand fence. | 2 | 2. 54 | 3 | 1 |
| Double-belt expedient concertina | 7 | 8. 9 | 10 | 3 |
| Triple-belt expedient concertina (pyramided) | 10. 5 | 13. 4 | 14 | 4 |
| Triple-belt standard Dannert concertina_ | 7. 5 | 9. 5 | 10 | 3 |

${ }^{1}$ Measurement ton 40 cubic feet.

## Section IV. CAMOUFLAGE

## 48. Issue Camouflage Materials

Issue camouflage materials include cotton twine nets, both ungarnished and garnished with vegetable fiber burlap in flat-top or drape patterns; camouflage net sets of the drape type comprised of two or more garnished nets with ancillary components; wire netting which can be garnished with vegetable fiber, steel wool, paints, wire, wire rope, cotton twine, fiber rope, wood and metal stakes and supports; and several miscellaneous items.

## 49. Nets and Net Sets

a. Individual nets are issued ungarnished or garnished with vegetable fiber (burlap) in flat-top pattern or in drape pattern.
(1) Flattops. A flattop consists of a twine net (wire for more permanent installations) that is stretched parallel with the ground and garnished with natural on artificial materials to blend with the surrounding terrain. A flattop should extend past the area to be concealed on each side by a distance equal to twice the height of the flattop above the ground. For complete concealment flattops should be no more than three feet above the general height of the vegetation at their edges.
(2) Drape nets. Drape nets (individual) are pregarnished twine nets, designed to provide concealment for vehicles, artillery, and other similar equipment. They are issued in the following sizes (in feet):
17 by $35 \quad 29$ by 29
22 by $22 \quad 36$ by 44
29 by $14 \quad 45$ by 45

Table 47. Charactoristics of Camouflage Net Sets, Drape Type

| Net set, drape | Size and number of nuts | Totul syuare | $\begin{aligned} & \text { Weight } \\ & \text { (pounds) } \end{aligned}$ | Cubage (feet) | Packaging |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $72^{\prime}$ by $88^{\prime}$ | $36^{\prime}$ by $44^{\prime}$ (4) | 6, 336 | 1, 070. 0 | 60.5 | 5 bags; 3 pole-carrying boses. |
| $58^{\prime}$ by $58^{\prime}$ | $29^{\prime}$ by $29^{\prime}$ (4) | 3,364 | 648. 0 | 34. 0 | 3 bags; 2 pole-carrying boxes. |
| $44^{\prime}$ by $44^{\prime}$ | $22^{\prime}$ by $22^{\prime}$ (4) | 1,936 | 365.5 | 21. 5 | 3 bags; 1 pole-carrying box. |
| $34^{\prime}$ by $35^{\prime}$ | $17^{\prime}$ by $35^{\prime}$ (2) | 1,190 | 306. 0 | 15.0 | 2 bags; 1 pole-carrying box. |
| $28^{\prime}$ by $29^{\prime}$ | $14^{\prime}$ by $29^{\prime}$ (2) | 812 | 145. 0 | 6.0 | 1 bug (nets). Ribs (loose). |
| $90^{\prime}$ by $90^{\prime}$ (Basic set) | $45^{\prime}$ by $45^{\prime \prime}$ (4) | 8, 100 | 1,320. 0 | 79.0 | 5 bags; 2 pole-carrying boxes 3 heavy-duty pole-carrying cascs. |
| With supplemental equipment $104^{\prime}$ by $118^{\prime}$. | $14^{\prime}$ by $29^{\prime}$ (12) ; $29^{\prime}$ by $29^{\prime}$ (2). | 12, 272 | 1, 713.0 | 111. 3 | 3 bugs. |
| $90^{\prime}$ by $180^{\prime}$ | $45^{\prime}$ by 45' (8)-------------1 | 16,200 | 2, 483. 0 | 151. 0 | 2 polc-currying boxes; 8 polecarrying cases; 10 canvas carrying bags. |

$b$. Camouflage nets garnished in drape pattern are also issued in sets. These sets contain two or more nets for assembly, garnished as a component to fit into the overall pattern of the set. Since these nets drape to the ground, they offer considerably better concealment than do the nets of the flattop pattern. Their principal character-istics are shown in table 47.

## 50. Garnishing Nets in the Field

a. Precolored cloth or cloth impregnated in the field is used to match garnished nets to local coloration. Percentages of colors usually required are shown in table 48.

Table 48. Color Percentages

| Tropical and summer temperate | Winter temperate | Desert terrain | All seasonal |
| :---: | :---: | :---: | :---: |
| Dark green, 70 percent. | Earth brown, 60 percent. | Sand, 80 percent | Dark green, 60 percent. |
| Light green, 15 percent. | Olive drab, 30 percent. | Olive drab, 10 percent. | Earth brown, 40 percent. |
| Field drab, 15 percent. | Earth red, 10 percent. | Light green, 10 percent. |  |

b. Materials and man-hours for garnishing twine net,--mesh 21/4 inches square, are shown in table 49.

Table 49. Camouflage Materials and Man-Hours Required for Garnishing Twine Net

| Size (feet) | Welght (pounds) |  | Cubage (euble feet) |  | $\begin{aligned} & \text { Number of garnlshiug strlps } \\ & 2^{\prime \prime} \text { by } 60^{\prime \prime} \end{aligned}$ |  | Number of rolls $2^{\prime \prime}$ by $300^{\prime}$ |  | A pproximate man-bours |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Flattop | Drape | Flattop | Drape | Flattop | Drape | Flattop | Drape | Flattop | Drape |
| 15 by 15 | 9 | 11.8 | 0.9 | 1. 18 | 234. 0 | 306 | 4 | 5 | 5 | 7-8 |
| 14 by 29 | 12 | 15. 8 | 1. 0 | 1. 31 | 422.0 | 550 | 7 | 9-10 | 14 | 19-20 |
| 22 by 22 | 15 | 19.6 | 1. 5 | 1. 96 | 454.0 | 594 | 8 | 9-10 | 14-15 | 19 |
| 17 by 35 | 20 | 26. 2 | 2. 0 | 2. 6 | 617.0 | 808 | 10 | 13-14 | 19 | 25-26 |
| 29 by 29 | 27 | 35. 2 | 3. 3 | 4. 3 | 874. 6 | 1, 142 | 14-15 | 19 | 30 | 40 |
| 36 by 44 | 51 | 66.9 | 5. 0 | 6. 6 | 1, 645. 0 | 2, 160 | 27 | 36 | 55 | 60 |
| 45 by 45 | 60 | 78.5 | 6.0 | 7. 9 | 2, 110. 0 | 2, 760 | 35 | 46 | 60 | 62-63 |

## 51. Paints and Adhesives

Basic data for various types of paints and adhesives used for camouflage purposes are given in table 50 and stains used in the field are given in table 50.1. Supplementing this, table 51 gives data on tone-down materials for use on concrete, and table 52 gives data on adhesives used with granules. Table 52.1 gives the coverage data of paints and adhesives on certain types of matcrials. For further details see FM 5-22.

| Type of material | How issued | Colors | How prepared | Drying time | Resultant surface |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Paint, camouflage, resin oil emulsion and resin | Ready-mixed | FED SPEC TT-C-295. | Mix with water or mineral spirits. | About 24 hours.- | Flat finish. |
| Paint, camouflage, emulsifiable. | Paste | Standard camouflage colors'. | Mix with water or - organic solvents. | On wood or metal, not over 6 hours. | Flat and lusterless. |
| Paint, protein-binder, cold water. | Powder- | $\begin{aligned} & \text { FED SPEC } \\ & \text { TT-C-295. } \end{aligned}$ | Mix with water-----.--- | 48 hours to be slightly rain resistant; can handle in 6 hours. | Hard, flat surface. |
| Paint, paste, lusterless, gasoline removable. | Paste | White, in engr. depots; commercial, all colors. | Mix with gasoline or mineral spirits. | 15 to 60 min utes. | Flat. |
| Cement water paints. | Powder, cement; protein powder, modified cement; and oil paste, modified cement. | A range of light colors. | Mix with water.....--- | 30 minutes to 6 hours. | Hard, opaque, flat, lusterless. |
| Oil-type paints for runways. | Ready-mixed...... | White and yellow.-- | Ready for application; can thin with mineral spirits or turpentine. | $\begin{aligned} & \text { Less than } 1 \\ & \text { hour. } \end{aligned}$ | Flat (must be specified). |
| Paint, camouflage, bituminous emulsion, adhesive. | Ready-mixed.-.- | Dries to a blackish brown. | Mixed with watcr. For better penetration, add wetting agent. | To touch, 8 hours. | Medium gloss; dulls rapidly on exposure. |


| Cutbaek asphalt | Slow cure, medium cure, rapid cure. | Dark brown to black. |
| :---: | :---: | :---: |
| Primer, enamel undereoater, phenolic. | lReady-mixed.-.--- | Dull red, ycllow--- |
| Camouflage face paint | Stiek form------- | White troopsé, light green and loam. Colored, light green and siand. |
| Stains for wood surfuees | 3 types, all readymised. | Varies with manufucturer. |
| Field-expedient tentage stain No. 1. | Field expedient---- | Dark gray |
| Field-expedient tentage stain No. 2. | Ficld expedient...- | Dark gray. |
| Fabric dye- | Both liquid and powder. | Various |
| Paint, emulsified, field expedient. | Ficld expedient...- | Depends on range of earth eolors available. |


dient soap and elay or cliatomaceous carth.

Slow eure, diesel oil; me, kerosene; rapid cure, gaso-

Reatdy for use

Ready for use; can thin with mineral spirits or tinc.
id fold expedient soap, direeted
Mix with chareoal and water as directed.
Mix with salt and water and use as directed. res air sulv, or oil salvage or monter soil with? (Type I) ground clay or powdered carbon and gasoline; or (Type

Table 50. Camouflage Paints Adhesives-Continued

| Type of material | How issued | Colors | How prepared | Drying time | Resultant surface |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Field cxpedient soap (for field cxpedient paint). | Field expedient.- |  | Mix and treat, as directed, waste kitchen grease and wood ashes. |  |  |
| Raw molasses (for field expedient paint). | Liquid.-.-.-.--- | Brown----------- | Thin with water-.---.-- | Always sticky.-- |  |
| Used crankcase oil_- | Salvage | Brownish | Use as supplied or mix with native colored earths. | --- |  |
| Asphalt cement. | Commercial. |  |  |  |  |
| Canvas refinishing compound. | Ready-mixed_--- | Dark O.D., O.D., or grcen. Major unit commanders may requisition other colors. | Stir; dilutc with gasoline if needed. | At least 2 hours. | Mat finish. |
| Field expedient green vegetation adhesive. | Practically any green vegetation. |  | Boil fresh-cut plant material in water and treat as directed. | ------ |  |
| Field expedient starch adhesive. | Any food containing starch, such as flour, grains, potatoes, etc. |  | Prepare from raw materials as directed. |  |  |
| Glue-paste adhcsivc.---- | Field expedient...- |  | Combine, as directed, flour paste, glue sizing, resin-sizing, varnish, borax, and hot water. | -------------- |  |

Table 50.1. Field Expedient Stains


Table 51. Tone-down Materials For Use on Concrete

| Coating material | Contalner | Colors | Source | Durability | Preparation | Drying time (hours) | $\underset{\substack{\text { Clons }}}{\text { Climate limita- }}$ | Application |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Cutback asphalt (coal tar may be substituted). | 55 gal. drums. | Brownishblack. | Commercial, ${ }^{1}$ <br> Fed. Spec. SS-A671. | Good - - | Ready mixed: quick-dry, mediumdry, slowdry. | (Med) 24 | Requires dry surface and conditions. May be used at subfreezing temp. | Brushing; spray-ing-hand or pressure. |
| Coating compound, bituminous emulsion | 55 gal. drums. | Brownishblack. | $\begin{aligned} & \text { Commercial, }^{1} \\ & \text { MIL-P- } \\ & 3840 . \end{aligned}$ | Good - - | Ready mixed . | 48 | Can be applied to diamp surface. Temperature must be above $45^{\circ} \mathrm{F}$. Not good in tropics. | Brushing; pressure spraying. |
| Paint, water, paste. | 5 gal. can. | All camouflage colors. | Commercial, ${ }^{1}$ M1L-P-13340. | l'air- - | Must be thinned w/gatsoline or water, 1 to 1 by volume. Use gas or naphtha below freczing. | 6 | Cun be applied to damp surface. Good between $-40^{\circ}$ and $+160^{\circ} \mathrm{F}$. | Brushing; pressure spraying. |


| Pigmented sodium silicate. | Varies_.-- | All camouflage colors. | Commercial. ${ }^{1}$ | Good on rough surface, poor on smooth. | Concentrate thinned w/water is sprayed on surface followed by spraying with calcium chloride to set or fix. | N/A | Can be applied to damp surface. | Pressure spraving. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Paint, traffic. - | 1 gal. cans. | White_.-.-- | TT-P-115A - | Excellent for traffic surface. | Ready mixed | 1 | Dry, clean surface required. | Pressure spraying. |
| Xylene and tar (Rt. 2). <br> Kerosene and asphalt (similar to British pitch and creosote mix). | Varies-.-- | Brownishblack. | Commercial. ${ }^{1}$ | Fair-------- | Mix 80 tar to 0.20 xy lene. Mix 25 asphalt to 75 kerosene by volume. | Rapid.-.- | Dry, clean surface required. | Sprayinghand and pressure. |

[^14]Table 51. Tone-Down Materials For Use on Concrete—Continued

| Coating materlal | Coverage (square feet per gallon) | Thinners | Fire hazards during appleation | Effects of jet exhaust at warmup points | Sultable texturing materials | Remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Cutback asphalt (coal tar may be substituted). | 25 to 90.-.--- | Quick-gasoline; medium-kerosene; slow-diesel fuel. | High. <br> If coating is heavy will support combustion if fired by jet exhaust or other means. | Melting increases shininess and slipperiness. Possible fire. | Gravel; slatc chips. Wood chips if time is not a factor. | Not recommended for surface exposed to jet exhaust. |
| Coating compound, bituminous emulsion. | 25 to 90.----- | None.-.-...-. | Low - ------- | Will remove. Better than cutback asphalt but has similar drawbacks. | Asphalt chips, rubber chips, wood chips, other small granules. | Surfaces coated cannot later be painted with lasting success with any other typc paint. |
| Paint, water, paste. | 450 to 600...- | Water, gasoline, and naphtha. | High when gasoline and naphtha are used. Low with water. | Will remove but will not support its own combustion. | None-.-.- | None. |


| Pigmented sodium silicate. | Not available_ | Water-.-------.-- | None.- | Not available.... | None.------- | Good for limited types of surface. Traffic on smooth surface pulverizes brittle coating which then blows away or wâshes off. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Paint, traffic.--- | 300 to 350..-- | Turpentine, gasolene, naphtha. | Medium to high | Will blister and change color. | None.--------- | Best but costly. |
| Xylene and tar (Rt. 2). <br> Kerosene and asphalt (similar to British pitch and creosote mix). | Not available | Xylene, kerosene - | High---------- | Will remove. No fire hazard with thin film, may be with thick film. | None.--------- | Primarily a cheap stain. Has application and fire drawbacks. |

Table 52. Texturing Materials

| Texturing materials | Durability compared with reck chips (percent) | Abrasion | Coverage per ton in square yards | Sources |
| :---: | :---: | :---: | :---: | :---: |
| Wood chips 1' ${ }^{\prime \prime}$----- | 75 | Low | 800 | Tanneries, wood pulp concerns, paper mills. |
| Rock chips 1/2' ${ }^{\prime \prime}$------ | 100 | High_---- | 90 | Quarries and road building contractors. |
| Grave | 100 | Medium | 90 | Gravel pits. |
| Leather chips.......- | 75 | Low | 115 | Shoe and leather goods manufacturers. |
| Coffee beans | 75 | Low | 90 | Coffee growers. |
| Wood cubes....-...- | 60 | Low . . . - | 161 | Lumber (cubes made on site). |
| Fabric (burlap scraps or similar materials). | 30 | Low . . . - | 2,000 | Rag and textile concerns. |
| Plant mix, $114^{\prime \prime}$ open graded aggregate. | 100 | Medium ${ }_{\text {-- }}$ | 22 | Asphalt distributors. |
| Slag- | 80 | High_--- | 90 | Iron and steel blast furnaces. |
| Pine bough tips | 20 | Low - - - - | 400 | Local labor. |
| Pine cones. | 20 | Low---- | 161 | Local labor. |
| Excelsior | 30 | Low - - - - | 2,000 | Wood-pulp concerns. |
| Shredded coconut fiber (coir). | 15 | Low --.-- | 2,000 | Byproduct of cocoa manufacturing. |
| Redwood fiber.-.- | 30 | Low - - - - | 1, 600 |  |
| Cinders. | 90 | High.---- | 90 | RR. roundhouses, boilers, factories. |
| Feathers | 15 | Low - - - - | 20, 000 | Poultry slaughterhouses, mattress manufacturers. |
| Cottonseed hulls | 50 | Low | 3, 000 | Cotton gins. |
| Spanish moss------- | 10 | Low - - - - | 2, 000 | Local labor. |
| Paper, shredded...-- | . 05 | Low . . . - | 2, 000 | Paper mills, junk dealers. |
| Sawdust, $1 / 3^{\prime \prime} \ldots \ldots$ Tin cans------------ | 75 | Low - . . - | 3,000 | Lumber mills, furniture manufacturers, plywood mills. Salvage depots. |
| Leaves and chopped palm fronds. | 15 | Low | 2,000 | Local labor. |
| Seaweed--------- | 10 | Low - .-. - | 2, 000 | Local labor. |

Note. These flgures are approximate, for purpose of comparison and rough estimates.

Table 52.1. Coverage Data

| Coating material |
| :--- |

[^15]Table 52.1. Coverage Data-Continued

| Coating material | Glass |  |  |  | Coated or primed metal |  |  |  | Galvanized Metal |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Brushing |  | Spraying |  | Brushing |  | Spraylug |  | Brushtug |  | Spraythg |  |
|  | Square feet per gallon | $\left\lvert\, \begin{gathered} \text { Man-lours } \\ \text { per } 100 \\ \text { sq. ft. } \end{gathered}\right.$ | Square fect per gallon | Square fect per hour | Square <br> fect per <br> gallon | $\begin{aligned} & \text { Man-hours } \\ & \text { per } 100 \\ & \text { sq. ft. } \end{aligned}$ | Square fect per gallon | Square feet per hour | Square fect per gallon | $\left\lvert\, \begin{gathered} \text { Mau-hours } \\ \text { per } 100 \\ \text { sq. ft. } \end{gathered}\right.$ | Square feet per gullon | Sçuare feet per hour |
| Paint, water, paste MIL-P13340 (table I) | 600 | $1 *$ | 750 | 3, 000 | 600 | 1 | 750 | 3, 000 | 600 | 1 | 750 | 3, 000 |
| Xylene and tar (R-2); kerosene and asphalt (table II) |  |  |  |  |  | , |  |  |  |  |  |  |
| Paint, temporary, paste MIL-P13983 (table I) | 500 | 1 | 600 | 3, 000 | 500 | 1 | 600 | 3, 000 |  |  |  |  |
| Cutback asphalt types I, II, III (table I) Fed. SSA-671 | 30 | 1. 66 | 30 | 900 | 30 | 1. 66 | 30 | 900 | 30 | 1. 66 | 30 | 900 |
| Used crankcase oil (table III) . - |  |  |  |  |  |  |  |  |  |  |  |  |
| Stains, table I |  |  |  |  |  |  |  |  |  |  |  |  |
| Coating compound, bituminous emulsion MIL-P-3840 (table I) | 45 | 1. 1 | 45 | 1, 350 | 45 | 1. 1 | 45 | 900 | 45 | 1. 1 | 45 | 1,350 |
| Asphalt cement (table III) -...- |  |  |  |  |  |  |  |  |  |  |  |  |
| Water, paint, paste MIL-P18358 (table I) | 500 | 1 | 600 | 3, 000 | 500 | 1 | 600 | 3, 000 |  |  |  |  |

Table 52.1. Coverage Data-Continued

| Coating material | Mineral-coated roofing |  |  |  | Rubber |  |  |  | Wood |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Brushing |  | Spraying |  | Brushing |  | Spraying |  | Brushing |  | Spraying |  |
|  | Square <br> feet per <br> gallon | $\begin{gathered} \text { Man-hours } \\ \text { per } 100 \\ \text { sq. It. } \end{gathered}$ | Square feet per gallon | Square <br> reet per hour | Square reet per gallon | $\begin{gathered} \text { Man-hours } \\ \text { per 100. } \\ \text { sq. ft. } \end{gathered}$ | Square feet per gallon | Square reet per hour | Square feet per gallon | Man-hours per 100 sq. ft. | Square feet per gallon | Square reet per hour |
| Paint, water, paste MIL-P13340 (table I) | 450 | 1 | 600 | 3, 000 | 450 | 1 | 600 | 3, 000 | 450 | 1 | 600 | 3,000 |
| Xylene and tar (R-2); kerosene and asphalt (table II) |  |  |  |  |  |  |  |  |  |  |  |  |
| Paint, temporary, paste, MIL-P-13983 (table I) |  |  |  |  |  |  |  |  |  |  |  |  |
| Cutback asphalt types I, II, III (table I) Fed. SSA-671 | 30 | 1. 66 | 30 | 900 |  |  |  |  | 30 | 1. 66 | 30 | 900 |
| Used crankcase oil (table III).-- |  |  |  |  |  |  |  |  |  |  |  |  |
| Stains, table I |  |  |  |  |  |  |  |  | 200 | 1 | 200 | 3,000 |
| Coating compound, bituminous emulsion MIL-P-3840 (table I) $\qquad$ | 45 | 1. 1 | 45 | 1,350 |  |  |  |  | 45 | 1. 1 | 45 | 1,350 |
| Asphalt cement (table III) |  |  |  |  |  |  |  |  |  |  |  |  |
| Water, paint, paste MIL-P18358 (table I) |  |  |  |  | 400 | 1 | 475 | 2,850 | 400 | 1 | 475 | 2, 850 |

Table 52.1. Coverage Data-Continued

| Coating material | Grass |  |  | Earth, sand, and stabilized soll |  |  | Glass fiber and steel wool |  | Feather-garnished and mineral-fiber-garnisinednetting |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Sprayling |  |  | Spraying |  |  | Spraylug |  | Spraylng |  |
|  | Square feet per gallon | Sprayer (square feet per hour) | $\left\lvert\, \begin{array}{c\|} \text { Pressure } \\ \text { distributor } \\ \text { (square } \\ \text { feet) } \end{array}\right.$ | Square feet per gallon | Sprayer (square feet per hour) | Pressure distributor (square feet) | Square feet per gallon | Sprayer (square feet per hour) | Square feet per gullon | Sprayer (square fect per hour) |
| Paint, water, paste MIL-P-13340 (table I) |  |  |  |  |  |  | 600 | 3, 000 | 600 | 6, 000 |
| Xylene and tar (R-2); keorsene and asphalt (table II) |  |  |  |  |  |  |  |  |  |  |
| Paint, temporary, paste, MIL-P13983 (table I) . |  |  |  |  |  |  |  |  |  |  |
| Cutback asphalt types I, II, III (table I) Fed. SSA-671 | 100 | 2, 000 | 8, 000 | 100 | 2, 000 | 8, 000 |  |  |  |  |
| Used crankcase oil (table III) |  |  |  | 20 | 60 | 1,600 |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| Coating compound, bituminous emulsion MIL-P-3840 (table I) | 100 | 2, 000 | 8, 000 | 100 | 2, 000 | 8,000 |  |  |  |  |
| Asphalt cement (table III) |  |  |  |  |  |  |  |  |  |  |
| Water, paint, paste MIL-P-18358 (table I) |  |  |  |  |  |  |  |  | 350 | 5, 250 |

${ }^{1}$ Cutbaek asphalt types II and III only.
${ }^{2}$ Cutback asphalt type I ouly.

## CHAPTER 6 ROADS AND BRIDGES

## Section I. MILITARY ROADS

## 52. General

FM 5-36 covers route rcconnaissance and classification. TM 5-250 deals with reconnaissancc, design, construction, maintenance, and repair ol roads and airfields. TM 5-252 deals with the use of road and airficld construction equipment. TM 5-253 deals with bituminous construction. TM $5-560$ includes material on road construction in Arctic conditions. TM 5-624 deals with the repair of roads and runways. TM 5-260 covers the principles of bridging. TM 5-271 discusses light stream crossing equipment. Numerous TM's of the 5 - series describc individually the various types of standard bridging, and of road, bridge, and airfield construction equipment.

## 53. Design

$a$. The specifications listed in table 53 will, under most conditions, give a combat road which will meet military requircments; conserve time, labor, equipment, materials, and transportation; and provide at least minimum driving salety. Those specifications related primarily to safcty arc not to be considered as "must" specifications, but rather specifications to be met whencvel possible and without undue sacrifice of other considerations. Although they are not rigidly required, this docs not mean that they are not important.
b. Figures 9 and 10 are a cross scction and a perspective illustrating road nomenclature.

Table 53. Summary of Military Road Specifications

|  | Characteristic | Specification |
| :---: | :---: | :---: |
| 1 | WIDTH: <br> Traveled way (single lane) <br> Traveled way (two lanes) - <br> Shoulders (eaeh side) $\qquad$ <br> Clearing $\qquad$ | Minimum-12 feet. <br> Minimum-22 feet. 23 Fm's 3a <br> Minimum-4 feet. <br> Minimum-6 feet on each side of roadway. |
| 2 | ALINEMENT (based on 25 to $35 \mathrm{~m} . \mathrm{p} . \mathrm{h}$.$) :$ <br> Grades: <br> Absolute maximum $\qquad$ <br> Normal maximum $\qquad$ <br> Desirable maximum $\qquad$ | Lowest maximum gradability of vehieles for whieh road is built. <br> 10 pereent. <br> Tangents and gentle eurves, less than 6 pereent; sharp eurves, less than 4 percent. |

Table 53. Summary of Military Road Specificalions—Continued

|  | Characteristics | Specification |
| :---: | :---: | :---: |
| 2 | ALINEMENT-Continued |  |
|  | Horizontal curve radius.- | - Minimum-150 feet. |
|  | Vertical curve length: |  |
|  | Invert curves. | 100 feet minimum for each 4 percent algebraic difference in grades. |
|  | Overt curves_ | 125 feet minimum for each 4 percent algebraic difference in grades. |
|  | Sight distance: |  |
|  | Nonpassing | Absolute minimum-200 feet. |
|  | Passing. | Absolute minimum-350 feet. |
| 3 | LOAD CAPACITY: |  |
|  | Road proper | Sustain 10,000-pound wheel load. |
|  | Bridges----- | Accommodate using traffic. |
| 4 | SLOPES: |  |
|  | Shoulders. | 3/4 inch per foot. |
|  | Crown (gravel and dirt) | 1/2 to $3 / 4$ inch per foot. |
|  | Crown (paved) . .-... | $1 / 4$ to $\frac{1}{2}$ inch per foot. |
|  | Superelevation | 1/4 to 11/4 inch per foot. |
|  | Cut | Variable. |
|  | Fill | Variable. |
| 5 | MISCELLANEOUS: |  |
|  | Overhead clearance | Minimum-14 feet. |
|  | Traffic volume | 2,000 vehicles per day. |
|  | Turnouts (single lane) | Minimum-every $1 / 4$ mile. |



Figure 9. Typical cross section illustrating road nomenclature.


Figure 10. Perspective of road illustrating road nomenclature.

## 54. Construction

a. Earthwork. Volumes of earth to be moved are eomputed in order to faeilitate the seheduling of equipment and the balancing of cut and fill. This is generally done by using the average end area formula or the average eut or fill table.
(1) The average end area formula is:

$$
V=\frac{\left(A_{1}+A_{2}\right) L}{54}
$$

where,

$$
\begin{aligned}
& V=\text { volume, cu. yds. } \\
& A_{1} \text { and } A_{2}=\text { end areas, sq. ft. } \\
& L=\text { distanee between end areas, } \mathrm{ft} .
\end{aligned}
$$

(2) Having only the centerline profile plotted and the grade cstablished, earthwork can be estimated from table 54.
b. Drainage.
(1) Ditehes.
(a) The size and gradient of ditches and open ehannels may be determined by Manning's formula:

$$
Q=A \frac{1.486}{n}{ }_{R} 2 / 3{ }_{s} 1 / 2
$$

where,
$Q=$ discharge, cu. ft./sec.
$A=$ cross-sectional area of flow, sq. ft .
$R=$ hydraulic radius $\left(\frac{\text { area of section }}{\text { wetted perimeter }}\right), \mathrm{ft}$.
$S=$ slope, feet/foot.
$n=$ coefficient of roughncss.

1. The desirable grades are between 0.5 percent and 4 percent.
2. The coefficient $n$ varies between 0.025 for ditches in good condition and 0.040 for ditches in poor condition.
(b) Maximum mean velocities permissible in table 55. The velocity is determined by $Q / A$.
(c) When the ditch grade excecds 4 percent, checkdams are used. Checkdams are spaced according to the formula:

$$
S=\frac{100 H}{A-B}
$$

where,
$S=$ distance between checkdams, ft
$H=$ height of chcekdam, ft
$A=$ grade of ditch, $\%$
$B=$ grade of water level, $\%$
(2) Culverts.
(a) The size culvert required to bridge a small stream (less than 10 feet) can be determined from

$$
A=\left(B_{1}+B_{2}\right) H
$$

where,
$A=$ cross-sectional area of culvert, sq. ft.
$B_{1}=$ width of stream at bottom, ft .
$B_{2}=$ width of stream at high water mark, ft .
$H=$ depth of high water mark, ft .
(b) The size of culvert required to carry surface runoff can be calculated using Manning's formula or Talbot's formula. The values of $n$ for use in Manning's formula are given in table 56.
Talbot's formula is used as an approximate method for hasty calculations and is:
$A=C \sqrt[4]{D^{3}}$
where,
$A=$ cross-sectional area of culvert, sq. ft.
$B=$ drainage area, acres
$C=$ cocfficient depending on terrain characteristics
Figure 11 is an alinement chart for solution of Talbot's formula.

Table 54. Volume of Culs and Fills in Cubic Yards per 100 Feel of Lenglh (for Level Sections)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| A verage depth of cut or helght of fill (feet) | Slde slope 1 to 1 -width of hase of cut or crown of flll (feet) ${ }^{\text {a }}$ |  |  |  |  |  |  |  | Add for each |  |  |
|  | 14 | 16 | 18 | 20 | 24 | 28 | 30 | 42 | feet of widt | slope is $1 / 2 \mathrm{to}^{\text {a }}$ 1 |  |
| 1. | 56 | 63 | 70 | 78 | 92 | 107 | 115 | 159 | 7 | 2 | 4 |
| 2 | 1.19 | 133 | 148 | 163 | 192 | 222 | 237 | 326 | 15 | 7 | 15 |
| 3 | 189 | 211 | 233 | 256 | 300 | 344 | 367 | 500 | 22 | 16 | 33 |
| 4 | 267 | 296 | 326 | 356 | 415 | 474 | 504 | 682 | 30 | 30 | 59 |
| 5. | 352 | 389 | 426 | 463 | 537 | 611 | 648 | 870 | 37 | 46 | 93 |
| 6. | 444 | 489 | 533 | 578 | 667 | 756 | 800 | 1, 065 | 45 | 67 | 133 |
| 7----- | 544 | 596 | 648 | 700 | 803 | 907 | 959 | 1, 271 | 52 | 91 | 181 |
| 8 | 652 | 711 | 770 | 830 | 948 | 1,067 | 1, 126 | 1, 483 | 59 | 118 | 237 |
| 9 | 767 | 833 | 900 | 967 | 1,100 | 1,233 | 1, 300 | 1,700 | 67 | 150 | - 300 |
| 10 | 889 | 936 | 1, 037 | 1,111 | 1,259 | 1, 407 | 1, 481 | 1,928 | 74 | 185 | 370 |
| 11 | 1,019 | I, 100 | 1, 181 | 1,263 | 1,426 | 1, 589 | 1, 670 | 2, 159 | 82 | 224 | 448 |
| 12 | 1, 156 | I, 244 | 1,333 | 1, 422 | 1,600 | 1,778 | 1, 867 | 2, 400 | 89 | 267 | 534 |
| 13 | 1, 300 | 1,396 | 1,493 | 1,589 | 1,781 | 1,974 | 2, 070 | 2,649 | 96 | 313 | 626 |
| 14 | 1,452 | 1,556 | 1,659 | 1, 763 | 1, 970 | 2, 178 | 2, 281 | 2, 904 | 104 | 363 | 725 |
| 15. | 1, 611 | 1, 722 | 1,833 | 1,944 | 2, 166 | 2, 389 | 2, 500 | 3, 167 | 111 | 426 | 852 |
| 16. | 1, 778 | 1, 896 | 2,015 | 2, 133 | 2, 370 | 2, 607 | 2, 726 | 3, 437 | 119 | 474 | 948 |
| 17 | 1,952 | 2, 078 | 2, 204 | 2, 330 | 2, 581 | 2, 833 | 2,959 | 3, 715 | 126 | 534 | 1, 068 |
| 18. | 2, 133 | 2, 267 | 2, 400 | 2,533 | 2, 800 | 3, 067 | 3, 200 | 4,000 | 133 | 598 | 1, 196 |
| 19 | 2, 322 | 2, 463 | 2,604 | 2,744 | 3, 025 | 3, 307 | 3, 448 | 4,293 | 141 | 667 | 1, 334 |
| 20 | 2, 519 | 2, 667 | 2,815 | 2,963 | 3, 259 | 3, 556 | 3, 704 | 4,593 | 148 | 740 | 1, 480 |
| 21. | 2, 722 | 2, 878 | 3, 033 | 3, 189 | 3, 500 | 3, 811 | 3, 967 | 4,900 | 156 | 815 | 1, 630 |
| 22 | 2,933 | 3, 096 | 3, 259 | 3, 422 | 3, 748 | 4,074 | 4, 237 | 5,215 | 163 | 894 | 1, 788 |

[^16]Table 55. Maximum Mean Velocities Permissible in Unlined Ditches

| Material | Mean velocity (feet per second) |
| :---: | :---: |
| Uniformly graded sand and cohesionl | 0. 7-1. 5 |
| Well-graded sand | 1. 5-2. 5 |
| Silty sand. | 2. 5-3. 0 |
| Clays.. | 3. 0-5. 0 |
| Coarse gravel and cobbles. | 5. 0-8. 0 |

Table 56. Values of $n$ for Manning's Formula

| Boundary surface | Manning $n$ |
| :---: | :---: |
| Well-planed timber | 0. 009 |
| Finished concrete. | . 012 |
| Concrete and clay sewer pipe, smooth, with smooth, rounded connections. $\qquad$ | . 013 |
| Other concrete pipe with ordinary alinement and jointing, average brickwork, unplaned timber $\qquad$ | . 015 |
| Concrete laid in rough forms, poor brickwork, good rubble masonry - | . 017 |
| Corrugated metal pipe, bituminous paved invert. | . 019 |
| Corrugated metal pipe, plain and bituminous coated | . 021 |
| Canals and ditches, good condition. | . 025 |
|  | . 040 |

c. Quarry and Gravel-Pit Equipment. Table 57 gives the output capacity of standard quarry and gravel-pit equipment.


-
CHARACTER OF
TERRAIN

$A=c \sqrt[4]{D^{3}}$
A= AREA OF CULVERT OPENING IN SQUARE FEET
CECOEFFICIENT OEPENOING ON CHARACTER OF TERRAIN $O=$ ORAINAGE AREA IN ACRES

EXAMPLE - THE AREA OF CULVERT FOR A DRAINAGE AREA OF 500 ACRES IN GENTLY ROLLING TERAAINIC OEFFICIENT $C=0.4)$ IS 42 SQUARE FEET.(SEE OASHEO LINE, A OVE)
5.000
4.000
3,000

Figure 11. Alinement chart for solution of Talbot's formula.

Table 57. Output Capacity of Quarry and Gravel-Pil Equipment



See footnotes at end of tuble.

Table 57. Output Capacity of Quarry and Gravel-Pit Equipment-Continued


${ }^{1}$ Same as washing unit．
${ }^{2}$ Adequate．
${ }^{3}$ Conveyor capacity is adequate to handic output of units it serves．Belt speed is 300 or 400 f．p．m．

4 Same as feeder conveyor．
${ }^{5}$ Conveyor capactty is adequate to handic output of units it serves．Beit speed is 300 f．p．m．
－Plate width， $2042^{\prime \prime}$ ．Hopper size， $5^{\prime} 6^{\prime \prime}$ by $5^{\prime} 6^{\prime \prime}$ opening．Hopper eapacity：level 1 2／2 cuble yards；heaped 2 cubie yards．
${ }^{7}$ Beit 18 inches wide， $18^{\prime} 0^{\prime \prime}$ puiley eenters．
${ }^{8}$ Beit 18 inches wide， $20^{\prime} \mathbf{7}^{\prime \prime}$ pulley eenters．
${ }^{8}$ Beit 18 inches wide， $14^{\prime} 0^{\prime \prime}$ pulley eenters．
${ }^{10}$ Belt 18 inches wide， $7^{\prime} 11^{\prime \prime}$ puliey couters．

## 55. Maintenance

a. Ditches and culverts must be kept open on all roads. Maintenance and repairs required on various types of surface are shown in table 58.

Table 58. Road Maintenance and Repair

| Type of surface | Maintenance | Repair |
| :---: | :---: | :---: | :---: |
| Portland-cement <br> concrete, asphal- | Clean dust and dirt <br> from joints and | Repair by patching with bituminous <br> premix, or with original material. |

conete, asphal
tic concrete, brick, stone, or wood block.

Bituminous sur- . faces.
from joints and cracks and refill with hot asphalt, tar, or a cement grout.
Occasional renewal of wearing surface by adding seal coat with mineralaggregate cover.
premix, or with original material.

Soft spots and breaks: Remove surface; correct drainage, base and/or subgrade; trim and square area to be patched; replace surface with bituminous premix.
Ruts, waves, and shoves: Usually caused by excess bituminous material, improper curing or defective drainage. The latter may require complete removal of pavement. If pavement is roadmix type, scarify and disk material until broken up, blade from side to side of strip. If necessary add aggregate, reshape and roll. Apply seal coat if needed. In surface treatments; usually indicates bond between bituminous treatment and base course broken. Remove wearing course, recondition and reprime base, apply new surface treatment. Use surface material similar to original.
Worn and raveled surface: In mixed material, remove surface full depth over defective area, cut square or rectangular opening with vertical edges. Clean base and apply tack coat, place mix and tamp, roll and check surface. In penetration-macadam or similar surface, repair by surface treating affected area with material similar to original pavement.

Table 58. Road Maintenance and Repair-Continued

| Type of surface | Maintenance | Repalr |
| :---: | :---: | :---: |
| Untreated surfaces of grivel, crushed rock, sand-clay, etc. (includes surfaces treated with dust palliatives). | Reshape periodically, preferably while damp, using blade grader or road drag. If surface develops corrugations it should be scarified and reshaped. Periodically add additional surfacing to replace that worn and washed away. Dust palliatives may be applied periodically as needed during dry season. | Soft spots: Remove surface; correct base, subgrade or drainage difficulty; trim and square area replace and compact surfacing. Repair of soft spot may sometimes be made by adding new layer of surfacing, keeping it maintained while it is being compacted by traffic. |
| Earth. | Reshape periodically, preferably while damp, using blade grader or road drag. Dust palliatives may be applied periodically as needed during dry season. | Soft spots: Correct drainage and cover or mix with granular material to stabilize. |
| Corduroy | Maintain cover of brush and earth. Respike logs. | Reconstruct sections as required. |
| Plank | Replace broken timbers. Keep well spiked. | Reconstruct sections as required. |

b. Engineor units instruct and assist the using fores in the use of truck-drawn steel-edged timber drags for maintenance of interior roads in depots, bivouac areas, hospitals, and similar aroas.

## 56. Road Signs

$a$. The designs and specifications for materials for road signs are responsibilities of the Chief of Engincers. Making road signs is an engineer responsibility. Posting them is an engineer responsibility coordinated with the appropriate provost marshal and the highway traffic regulation offieer of the Transportation Corps regarding location and the number used. Operational responsibility for road signing is a command function.
b. Figures 12 through 19 show typical road signs of various categories. For further details see AR 420-72; the Manual on Uniform Traffic Control Devices dated 1948 (Public Roads Administration) as modified by the Revision dated 1954 (Bureau of Public Roads) ; and FM 5-36.


ALL DISKS HAVE MINIMUM DIAMETERS OF 1 FOOT.
Figure 12. Directional disk marking.


MAIN SUPPLY ROUTE 205 FRONT GOING TRAFFIC STRAIGHT ON


ALTERNATIVE FOR SUPPLY ROUTE 205 FRONTGOING TRAFFIC STRAIGHT ON


MAIN SUPPLY ROUTE 205 ERONT GOING TRAFFIC TURN RIGHT


LATERAL ROUTE 216 NORTH GOING TRAFFIC TURN RIGHT


ALTERNATIVE FOR MAIN SUPPLY ROUTE 205 TURN RIGHT


ALTERNATIVE FOR Lateral route 216 TURN RIGHT


ALTERNATIVE FOR MAIN SUPPLY ROUTE 205 REAR GOING TRAFFIC STRAIGHT ON

MAIN SUPPLY ROUTE 205 REAR GOING TRAF FIC Straicht on


Figure 18. Route signs.

(24" x 9")

( $40^{\prime \prime} \times 24^{\prime \prime}$ )

( $40^{\prime \prime} \times 24$ )

( VARIABLE SIZE)

$130^{\prime \prime} \times 24 "$

## FRANKFURT

( VERTICAL-24" HOFAZONTAL VARIABLE. MINIMMM-24")

## RDAD

 CLOSED```
(40" \times 24")
```

```
(40" \times 24")
```


## BRIDEE OUT

Figure 14. Guide signs.



(18" $\times 24$ "
(12" $\times 18$ ")



CURVE TO RIGHT
24" $\times 24$ "


WINDING CURVES

- $24 \times 24$


T-JUNCTION
$24^{\prime \prime} \times 24^{\prime \prime}$


SHARP CURVE TO RIGHT $24^{4} \times 24^{n}$


> RAILROAD CROSSING DIM. ( $30^{\circ \prime}$ DIA.)


PRIMARY ROAD CROSSING


Figure 16. Warning signs.


ALL SIGNS ABOVE $\left(24^{11} \times 24^{11}\right)$
Figure 16.-Continued


Figure 17. Bridge class and information signs.


Figure 18. Dual-class bridge signs.


Figure 19: Multilane bridge signs.

## Section II. STREAM CROSSING EQUIPMENT

## 57. General

The siting, design, and erection of standard, prefabricated, floating, and fixed highway bridges are covered in the TM 5-270-series. Construction and logistical data pertinent to these bridges are tabulated in FM 101-10. Prefabricated semipermanent steel highway bridges for $30-, 60$-, and 90 -foot spans are covered in TM 5-285; typical semipermanent highway and railroad trestle bridges in TM $5-286$; and prefabricated steel railroad bridges in the TM 5-370-series. TM 5-260 deals with the design principles underlying the construction, maintenance, and use of all types of military bridges.

## 58. Panel Bridge, Bailey Type, M2

For detailed information on the Bailey type M2 panel bridge, see TM 5-277.

## 59. Semipermanent Steel Highway Bridges, 30-, 60-, and 90-foot Spans

Data on semipermanent steel highway bridges, 30-, 60-, and 90-foot spans are given in table 59.

Table 59. Semipermanent Steel Highway Bridges, 30-, 60-, and 90-Foot Spans

| Item | Nominal length |  |  |
| :---: | :---: | :---: | :---: |
|  | 30 ft . | 60 ft . | 90 ft . |
| Type. | Deck I-beam | Deck I-beam | Through truss |
| Class | 50 | 50 | 50 |
| Caution class ${ }^{1}$ | 75 | 75 | 70 |
| Weight of one beam or truss, pounds. | 2, 600 | 10, 000 | 15,000 |
| Weight, structural steel and connections, pounds. | 12, 917 | 45, 788 | 61,654 |
| Measured tons, structural steel and connections $\qquad$ | 7.55 | 20. 31 | 48. 56 |
| Quantity of lumber, board feet | 3, 868 | 7, 544 | 10,608 |
| Measured tons, lumber.-.----- | 8. 05 | 15. 70 | 22. 10 |
| Man-hours to erect, average..- | 453 | 1, 042 | 1, 929 |
| Required abutment capacity, tons. $\qquad$ | 70.5 | 87.5 | 88.5 |

11 vehicle on bridge at a time, vehicle on center line of bridge, no braking or gear shifting.

## 60. Prefabricated Railroad Bridges

Therc are three bridges in this category: The I-beam railroad bridge (TM 5-371), the unit construction railroad bridge (TM 5-372), and the through-truss railroad bridge (TM 5-373). The relations between type, loading, span length, and maximum speed for the foregoing are given in tables 60, 61, and 62 . New equipment is under study which, if adopted, may take the place of the first two types and the semipermanent steel highway bridges described in TM 5-285 as well.

## 61. Floating Bridges

Data on floating bridges is given in tables 63 and 63.1.

## 62. Rafts

Data on rafts is given in table 64.

## 63. Boats

a. General. Below are summarized the principal characteristics of standard Army boats other than ponton boats. For further details see FM 5-271.
b. Assault Boat, Plastic, 16-Foot. The assault boat, plastic, 16-foot, replaced the assault boat, M2. It has a flat bottom, tapered bow, and square stern. It weighs 291 pounds and has a capacity of 3,375 pounds in currents up to 5 f.p.s. and 2,700 pounds in currents up to 8 f.p.s.

Table 60. I-Beam Railroad Bridge


Table 61. Unit Construction Railroad Bridge

| Type of bridge | Number of trusses | $\underset{\substack{\text { Spanth } \\ \text { lecet } \\ \text { fect }}}{ }$ | Maximum speed, mph, at Cooper's loadings of: |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | E-45 | E-421/2 | E-40 |
| Through truss. | Two-----.----- | 55 | 40 | 40 | 40 |
|  |  | 60 | 40 | 40 | 40 |
|  |  | 65 | 40 | 40 | 40 |
|  |  | 70 | 40 | 40 | 40 |
|  |  | 75 | 10 | 25 | 40 |
|  |  | 80 | (1) | 10 | 25 |
|  |  | 85 | (1) | (1) | 10 |
|  | Four-.-.------- | 75 | 40 | 40 | 40 |
|  |  | 80 | 40 | 40 | 40 |
|  |  | 85 | 40 | 40 | 40 |
| Deck | Two----------- | 55 | 40 | 40 | 40 |
|  |  | 60 | 40 | 40 | 40 |
|  |  | 65 | 40 | 40 | 40 |
|  |  | 70 | 40 | 40 | 40 |
|  |  | 75 | 10 | 25 | 40 |
|  | Three---------- | 75 | 40 | 40 | 40 |
|  |  | 80 | 40 | 40 | 40 |
|  |  | 85 | 40 | 40 | 40 |

1 Not permitted.
Table 62. Through-Truss Railroad Bridge

| Cooper's loadiugs | Maximum speeds in miles per hour for span lengths or: |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 92'-3' ${ }^{\prime \prime}$ | 102'-6" | H12'-9 ${ }^{\prime \prime}$ | 123'-0" | ${ }^{133}$-3' ${ }^{\prime \prime}$ | 143'-6" | 153'-9 ${ }^{\prime \prime}$ |
| Two standard locomotives and and train: |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| E-45. | 40 | 40 | 40 | 40 | 10 | 10 | (1) |
| E-421/2- | 40 | 40 | 40 | 40 | 20 | 10 | 10 |
| E-40- | 40 | 40 | 40 | 40 | 40 | 20 | 20 |
| One standard locomotive and train: |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| E-45- | 40 | 40 | 40 | 40 | 40 | 20 | 10 |
| E-421/2- | 40 | 40 | 40 | 40 | 40 | 40 | 20 |
| E-40----- | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
|  |  |  |  |  |  |  |  |

[^17]c. Bridge Erection Boat, 19-Foot. The bridge erection boat, 19-foot is designed to assist in the assembly of tactical floating bridges and the propulsion of light tactical rafts. It is also used for general utility work during the assembly of rafts or bridges; and it can be uscd for limited ferrying of personnel or equipment, although this is not economical. It is made of aluminum, with a rounded bow and square stern. It is 19 feet $21 / 2$ inches long and when services and with accessories weighs $3,800 \mathrm{lbs}$. Maximum allowable load is 3,000 lbs. It is powered by a 6 -cylinder marine-type engine driving a single propeller. There is a 2 -man crew.
d. Bridge Erection Boat, 27-Foot. The bridge, crection boat, 27-foot, has the same general functions as the 19 -foot type, but is designcd to propel the heaviest types of raft asscmbled for floating bridge scts. It is made of aluminum, in two sections, with a blunt bow and stern. It is 27 feet $1 / 2$ inch by 11 feet when assembled and with a pushing knee at the bow, and has a service weight of $6,800 \mathrm{lbs}$. Maximum allowable load is $3,000 \mathrm{lbs}$. It is powered by two 6 -cylinder marinetype engines driving twin propellers. There is a 2 -man crew.
e. Five-Man Canvas Pneumatic Reconnaissance Boat. The 5man canvas pneumatic reconnaissance boat is used primarily for rcconnaissance work and combat patrols. It is formed of inflatable cotton-duck tubing 16 inches in diameter, with a double cotton-duck bottom. It is 12 feet by 5 feet 8 inches when inflated, and weighs 120 lbs. with accessories. It has a squarc stern and raked triangular bow. Maximum cargo capacity is 2,000 lbs. The boat is propelled by paddles.
f. Boat, Reconnaissance, Pneumatic, Neoprene Coated Cloth. 3-Man Capacity. The boat is used for transporting 3 men on general rcconnaissance missions. The boat is $9^{\prime} 0^{\prime \prime}$ long and $4^{\prime} 0^{\prime \prime}$ wide. The weight of the boat is 31 pounds including carrying case, pump, repair kit, and 3 paddles. The boat is propelled by the use of paddles only.
g. Boat, Landing, Inflatable: Assault Craft, Nylon Cloth. 15-Man. The boat is used to transport men and equipment across strcams or other water obstacles during assault operations. The boat is propelled by either paddles or outboard motor. The length of the boat is $17^{\prime} 0^{\prime \prime}$ and the width is $6^{\prime} 3^{\prime \prime}$. The weight of the boat including paddles, repair kit, carrying case, and pumps is approximattly 260 pounds. The boat loaded with 3,300 pounds can be propelled with paddles in 5 -fps current and with a $25-\mathrm{hp}$ outboard in 8 fps current. It also can navigate in very turbulent water having velocities up to 12 fps when propelled by the $25-\mathrm{hp}$ motor.

Table 63. Classes of Floating Bridgès . .


${ }^{1}$ Transportation for bridge equipment only. Additional needed for any construction cquipment required, and for troops.
${ }^{2}$ A verage for trained troops and continuous daylight assembly. Allowanees are required for specific situations.
${ }^{3}$ Based on abutments at levels within 12 inehes of floating bridge deck level.
${ }^{4}$ Vehicle anywhere on width of bridge deck. Speeds: 15 mph recommended; up to 25 mph permitted.
${ }^{8}$ Center of vchicle within 12 inches of bridge centerline. Maximum speed 8 mph. Vclicle spacing 150 ft . No sudden stopping or acceleration.
${ }^{0}$ Center of vebicle within 9 inches of centerline and with guide. Maximum speed

3 mplı. One vehiele on bridge. No stopping, braking or gear shifting. ${ }^{7}$ Traffic capacitles arc for all traffic moving forward or rearward.
${ }^{9}$ Use 2 -space distance for 3 fps only; 1-bay distance for 4 and 5 fps; 2-bay distance for 6 and 7 fps.
${ }^{9}$ Normal assembly Reinforeed assembly
${ }^{10}$ Tanks weighing $u_{p}$ to 60 tons, and with an out-to-out track width of 143 inches or more, make normal erossings in stream velocitles up to 7 fps.
${ }^{11}$ Any class 50 vehicle with out-to-out track or tire width equal to or exceeding 144 inches can make a normal crossing in currents up to 5 fps .

| Bridge | Type of eonstr <br> FPS | Sare Normal |  |  |  |  | Caution |  |  |  |  | Risk |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 3 | 5 | 7 | 9 | 11 | 3 | 5 | 7 | 9 | 11 | 3 | 5 | 7 | 9 | 11 |
|  | Normal..--------- | 8 | 6 | 5 | ---- | ---- | 8 | 6 | 5 | ---- | -- | 9 | 7 | 6 | ---- | --- |
| - | Rein( ------- | 13 | 0 | 7 | -- | --- | 13 | 11 | 9 | --- | --- | 14 | 12 | 0 | ---- |  |
| Widened steel treadway bridge (w/plywood tdwy (1)-- |  | $\begin{array}{r} (45) \\ 50 \end{array}$ | $\begin{array}{r} (45) \\ 50 \end{array}$ | $\begin{array}{r} (35) \\ 40 \end{array}$ | $\begin{array}{r} (25) \\ 30 \end{array}$ | $\begin{gathered} (12) \\ 15 \end{gathered}$ | $\begin{array}{r} (48) \\ 51 \end{array}$ | (47) 50 | (43) 46 | $(31)$ <br> 34 | $\begin{array}{r} (16) \\ 10 \end{array}$ | $\begin{array}{r} (55) \\ 58 \end{array}$ | (54) | (52) 55 | $\begin{gathered} (41) \\ 44 \end{gathered}$ | (25) 28 |
|  | Normal | ${ }_{65}^{(60)}$ | ${ }^{(55)}$ | $\begin{array}{r} (45) \\ 55 \end{array}$ | $\begin{array}{r} (35) \\ \quad 45 \end{array}$ | $\stackrel{(22)}{(25}$ | $\begin{array}{r} (65) \\ 70 \end{array}$ | $\begin{gathered} (62) \\ 67 \end{gathered}$ | $\begin{array}{r} (56) \\ 61 \end{array}$ | (45) 49 | $\begin{array}{r} (34) \\ 37 \end{array}$ | $\begin{array}{r} (75) \\ 79 \end{array}$ | (72) $\begin{array}{r} 67 \\ 77 \end{array}$ | (67) 72 | $\begin{gathered} (57) \\ 62 \end{gathered}$ | (46) 50 |
|  | Reinf. (2)... | $\begin{gathered} (85) \\ 85 \end{gathered}$ | $\begin{array}{\|c} \hline(85) \\ 85 \end{array}$ | $\begin{gathered} (85) \\ 85 \end{gathered}$ | $\begin{gathered} (65) \\ 70 \end{gathered}$ | $\begin{array}{r} (30) \\ 35 \end{array}$ | $\begin{array}{r} (90) \\ 90 \\ \hline \end{array}$ | $\begin{gathered} (90) \\ 90 \end{gathered}$ | $\begin{array}{r} (90) \\ 90 \end{array}$ | $\begin{array}{r} (75) \\ 79 \end{array}$ | $\begin{array}{r} (47) \\ 51 \end{array}$ | $\begin{gathered} (100) \\ 100 \end{gathered}$ | $\begin{array}{\|r} (100) \\ 100 \end{array}$ | $\begin{array}{r} (100) \\ 100 \end{array}$ | $\begin{array}{r} (90) \\ 03 \end{array}$ | (70) 74 |
| M4 bridge.. | Normal (3) -- | $\begin{gathered} (60) \\ 60 \end{gathered}$ | $\begin{gathered} (60) \\ 60 \end{gathered}$ | $\begin{array}{r} (45) \\ 50 \end{array}$ | $\begin{gathered} (30) \\ 35 \end{gathered}$ | $\begin{gathered} (18) \\ 20 \end{gathered}$ | $\begin{gathered} (68) \\ 68 \end{gathered}$ | $\begin{array}{r} 65) \\ 65 \end{array}$ | $\begin{gathered} (58) \\ 59 \end{gathered}$ | $\begin{gathered} (44) \\ 46 \end{gathered}$ | $\begin{array}{r} (20) \\ 31 \end{array}$ | (72) 72 | $\begin{gathered} (68) \\ 68 \end{gathered}$ | (61) 52 | (53) <br> 54 | $(37)$ 39 |
|  | Reinf. (4).. ... | $\begin{array}{r} (100) \\ 100 \end{array}$ | $\begin{array}{r} (100) \\ 100 \end{array}$ | $\begin{array}{r} (100) \\ 1-0 \end{array}$ | $\begin{array}{r} (70) \\ 70 \end{array}$ | $(35)$ 40 | $\begin{array}{r} (105) \\ 105 \end{array}$ | $\begin{array}{r} (105) \\ 105 \end{array}$ | $\begin{array}{r} (105) \\ 105 \end{array}$ | (85) 85 | $\begin{array}{r} (55) \\ 55 \end{array}$ | $\begin{array}{r} (110) \\ 110 \end{array}$ | $\begin{array}{\|r} (110) \\ 110 \end{array}$ | $\begin{array}{r} (110) \\ 110 \end{array}$ | $\left\lvert\, \begin{array}{r} (100) \\ 100 \end{array}\right.$ | (70) 70 |
|  |  | (50) | (45) | (40) | (30) | (25) | (60) | (58) | (54) | (45) | (35) | (68) | (66) | (62) | (54) | (43) |

Notes. 1. Whecled and track vehicles have the same rating
2. Upper figure represents whecl load class. Example (43)

Lower figure represents tracked load elass.
3. (1) Vehleles rcquired to use plywood treadway lane limlted to Class 16 Safe, Class 18 Cautlon, Class 24 Risk.
4. (2) Ratings given are for floating portlon of brldge. End span ratings with present superstrueture limited to Class 70 Safe , Class 80 Caution, and

Class 90 Risk. Development of satisfactory landing bay not yet complete.
5. (3) Ratings given are for an 18 -balk roadway and a 22 -balk deck.
6. (4) Ratings given are for a 20 -balk roadway and a 24 -balk deck in the floatling portion, and a 20 -balk roadway and a 22 -balk deck with a superimposed deck in the end span.

Table 64. Classes of Rafts

*Number in parcntheses represents whecled vehicle class. Number without parentheses represents tracked vchicle class. See notes at end of table.

Table 64. Classes of Rafts-Continued
$\stackrel{\rightharpoonup}{\mathbf{\infty}}$



| Operating characteristics of rafts | Stream width (fect) |  |  |
| :---: | :---: | :---: | :---: |
|  | 250 | 500 | 1,000 |
| Number of round trips per hr in currents of 5 fps in daylight (reduce 50\% for night or adverse conditions)....... | 10 | 6 |  |
| Number of ralts which can be used efficientiy at one site. $\qquad$ | 1 | 2 | 3 |

${ }^{*}$ Number in parentheses represents wheeled vehicle class. Number without parentheses represents traeked vebicle class.
a Measured from outside edge to outside edge of end pontons or tloat saddle beams. b Capacities are based on loading rafts with eenter of gravity of loads $6^{\prime \prime}$ downstream from top of raft and on properly inflated floats.
c One 19-foot bridge erection boat per raft, in current of 9 fps .
d One 19 -foot bridge ercetion boat may he used in currents not over 5 fps . In eurrents of 5 fps and over, normally two 19 foot bridge erectlon boats may be substituted for one 27 -foot boat.
e Extreme caution is required in loading and unloading vehicles weighing more than 70 tons.
${ }^{\text {t }}$ Roadway wilth consists of 18 balk hetween curbs wltit 22 baik overall.
g Roadway width consists of 17 baik hetween curbs with 20 balk overall.

## 64. Nonstandard Fixed Bridges

a. Basic Structural Design. Design loads, allowable working stresses, properties of sections, and other data on structural design are given in chapter 9 and in standard handbooks in unit libraries.
b. Bridge Design and Construction. The design, construction, and capacity estimation of fixed timber bridges are covered in TM 5-260. Typical designs for nonstandard, semipermanent fixed highway and railroad bridges, with man-hour and material requirements, are given in TM 5-286. The data therein and in table 65 are based generally on experience personnel and good working conditions and on the use of power tools wherever possible.

Table 65. Bridge Construction Man-Hour Data

| Operation | Unit | Man-hours per unit | Number of men in crew |
| :---: | :---: | :---: | :---: |
| Steel: |  |  |  |
| Handling ${ }^{1}$ | Ton | 7. 000 | 7 |
| Bolting | Bolt. | . 060 | 2 |
| Chipping | Lin ft. | . 083 | 1 |
| Cutting (oxyacetylene) | Lin ft - | . 067 | 2 |
| Drilling | Lin ft . | 3. 200 | 2 |
| Driving steel piles_ | Lin ft. | . 133 | 8 |
| Span erection | Ton | 2. 500 | 9 |
| Tower erection | Ton. | 3. 500 | 9 |
| Laying out | Hole. | . 040 | 2 |
| Pattern making |  |  | 2 |
| Reaming ( $10 \%$ of all holes) | Hole_ | . 067 | 2 |
| Riveting fabrication | Rivet | . 100 | 4 |
| Riveting erection. | Rivet | . 150 | 4 |
| Welding. | Lb_ | . 700 | 2 |
| Timber: |  |  |  |
| Handling ${ }^{2}$ | Bd ft | . 010 | 7 |
| Boring- | Lin $\mathrm{ft}^{\text {- }}$ | . 100 | 2 |
| Driving driftbolts. | Bolt | . 017 | 1 |
| Bolting | Bolt | . 133 | 2 |
| Driving nails | Nail. | . 003 | 1 |
| Driving spikes | Spike | . 008 | 1 |
| Driving piles. | Lin ft_ | . 200 | 8 |
| Handling: |  |  |  |
| Span erection_ | Bd ft | . 004 | 9 |
| Tower erection | Bd ft | . 006 | 9 |
| Laying out. | Bd ft. | . 004 | 2 |
| Sawing (except piles) | Sq ft. | . 033 | 2 |
| Sawing piles. | Pile | . 167 | 2 |
| Excavation, hand - | Cu yd | 1. 000 | 7 |
| Cement handling. | Bbl | . 133 | 9 |
| Piles handling. | Pile | 1. 000 | 7 |
| Sand and gravel handling | Cu yd. | . 500 | 5 |
| Concrete mixing and placing-- | Cu yd. | 2. 000 | 24 |
| Scaffolds placement and removal | Cu yd |  | 4 |

[^18]
## 65. Highway Bridge Stringers

a. For two-lane bridges with an 18 - to 30 -foot roadway and a 6 -inch timber floor, in which the stringer depth is not less than $1 / 18$ of the span, the total section modulus required for timber stringers for various classes and spans is shown in table 66. For a single-lane bridge less than 18 feet wide, use 0.5 of the section modulus tabulated. For round timber stringers, use 0.6 of diameter as width, and diameter as depth.
$b$. For stringer depths from 6 to 24 inches, the section modulus per inch width of rectangular timber stringers is tabulated below. (For spans less than 13 times the stringer depth, examine for horizontal shear using the data in paragraph 163c.)

| Depth_---------------- | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :--- |
| Section modulus-------- | 6 | 11 | 16 | 24 | 33 | 43 | 54 | 67 | 81 | 96 |

$c$. Under the same conditions as in $a$ above as to widths and number of lanes, and where the stringer depth is not less than $1 / 30$ of the span, the total section modulus required in steel stringers is shown in table 67.
d. Section moduli for various' steel beams are given in paragraphs 151 to 160 .
e. Examples:
(1) A bridge with a 22 -foot roadway has a timber floor carried by six 6- by 16 -inch stringers over a 13 -foot span. Determine the class. Section modulus from $b$ above is 43 by $36=1,548$. By interpolation in the table in $a$ above, the class is 23 .
(2) Determine the number of 24 WF 76 stringers for a one-lane class 40 bridge with a 6 -inch timber floor and a span of 60 feet. From $c$ above, a total section modulus of 1,935 is required for a two-lane bridge; $0.5 \times 1935$ or 968 is the total section modulus required for one lane. From paragraph 139 , a 24 WF 76 has a section modulus of $175.4 ; 968 / 175.4=$ 5.5; therefore, use 6 stringers.

## Section III. CABLEWAYS AND TRAMWAYS

## 66. Characteristics

Logistical data and other characteristics of cableways and tramways are shown in table 68. For further details see TM 5-270.

## 67. Details

Details of the cableways and tramways listed in table 61 are given in figures 20 through 23.

Table 66. Section Modulus Required for Two-Lane Bridges, 18- to S0-Fool Roadway with 6-Inch Timber Floor (Timber Stringers)

| 13 feet |  | 15 feet |  | 17 feet |  | 19 feet |  | 21 feet |  | 23 feet |  | 25 feet |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | . Scction modulus | $\begin{aligned} & \text { Class } \\ & \mathrm{W} / \mathrm{T} \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & W / \mathbf{T} \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | Section modulus | $\begin{gathered} \text { Class } \\ W / T \end{gathered}$ | Scetion modulus | $\begin{aligned} & \text { Class } \\ & \mathrm{W} / \mathrm{T} \end{aligned}$ | Sectlon modulus | $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | Section modulus |
| 8 | 600 | 8 | 830 | 8 | 985 | 8 | 1135 | 8 | 1320 | 8 | 1490 | 8 | 1655 |
| 12 | 870 | 12 | 1070 | $12^{\prime}$ | 1270 | 12 | 1480 | 12. | 1700 | 12 | 1970 | 12 | 2232 |
| 16 | 1120 | 16 | 1375 | 16 | 1645 | 16 | 1934 | 16. | 2235 | 16 | 2545 | 16 | 2830 |
| 20 | 1375 | 20 | 1695 | 20 | 2050 | 20 | 2395 | 20 | 2775 | 20 | 3125 | 20 | 3485 |
| 24 | 1615 | 24 | 2030 | 24 | 2450 | 24 | 2855 | '24 | 3245 | 24 | 3680 | 24 | 4130 |
| $35 /$ |  | $35 /$ |  | $40 /$ |  | $40 /$ |  | $40 /$ |  | $40 /$ |  | 40/30 |  |
| /30 | 1750 | 30 | 2270 | $/ 30$ | 2695 | 130 | 3285 | $/ 30$ | 3750 | 130 | 4305 | $\bigcirc 30$ | 4735 |
| 50\% |  | 55, |  | $55 /$ |  | $60 \%$ |  | 60\% |  | $60 / 40$ |  | $60 / 40$ |  |
| 40 | 2200 | /40 | 2790 | 40 | 3445 | $\bigcirc$ | 4130 | 40 | 4795 | \%40 | $\therefore 5430$ | 450 | 6145 |
| $60 / 50$ |  | $65 / 50$ |  | 70/50 |  | $70 / 50$ |  | $70 / 50$ |  | 75/50 |  | $75 / 50$ |  |
| 150 | 2585 | /50 | 3355 | /50 | 4160 | /50 | 4905 | 85 | 5735 | 85 | 6565 | 85 | 7395 |
| $70 / 60$ | 2925 | 75/60 | 3695 | $80 / 60$ | 4720 | 80/60 | 5690 | 85/60 | 6690 | 85/60 | 7740 | $85 / 60$ | 8825 |
| 75 |  | 80 |  | $90 \%$ |  | 100\% |  | 100\% |  | 100/7 |  | 105/ |  |
| $/ 70$ | 3180 | $/ 70$ | 4210 | $/ 70$ | 5240 | /70 | 6360 | /70 | 7450 | $/ 70$ | 8600 | 770 | 9865 |

[^19]Table 67. Section Modulus Required for Two-Lane Bridges, 18- to 30-foot Roadway with 6-Inch Timber Floor (Steel Stringers)
[Various span lengths in feet]

| 15 feet |  | 20 feet |  | 25 fect |  | 30 fect |  | 40 feet |  | 50 feet |  | 60 feet |  | 80 feet |  | 100 feet |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} \text { Class } \\ W / T \end{gathered}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & \text { W/T } \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & \mathrm{W} / \mathrm{T} \end{aligned}$ | Sectlon modulus | $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & \mathrm{W} / \mathrm{T} \end{aligned}$ | Section modulus | $\begin{aligned} & \text { Class } \\ & W / T \end{aligned}$ | Section modulus |
| 8 | 85 | 8 | 120 | 8 | 165 | 8 | 210 | 8 | 310 | 8 | 430 | 8 | 550 | 8 | 895 | 8 | 1300 |
| 12 | 120 | 12 | 160 | 12 | 220 | 12 | 275 | 12 | 410 | 12 | 585 | 12 | 775 | 12 | 1195 | 12 | 1690 |
| 16 | 140 | 16 | 210 | 12 | 280 | 16 | 360 | 12 | 535 | 16 | 705 | 16 | 920 | 16 | 1415 | 16 | 2000 |
| 20 | 170 | 20 | 255 | 20 | 345 | 20 | 440 | 20 | 640 | 20 | 880 | 20 | 1145 | 20 | 1755 | 20 | 2465 |
| 24 | 205 | 24 | 305 | 24 | 410 | 24 | 515 | 24 | 745 | 24 | 1020 | 24 | 1330 | 24 | 2025 | 24 | 2830 |
| 35/ |  | $40 /$ |  | $40 /$ |  | $40 /$ |  | 35/ |  | 35/ |  | 30\% |  | 30/ |  | 30/ |  |
| 550 | 235 | 630 | 350 | 30 | 480 | \% 30 | 615 | 30 | 885 | 30 | 1190 | /30 | 1500 | 30 | 2305 | 30 | 3275 |
| 55/40 |  | $60 / 40$ |  | $60 / 40$ |  | $60 / 4$ |  | $50 /$ |  | 45/40 |  | 40/40 |  | 40/40 |  | 40/40 |  |
| 65 | 285 | 70 | 450 | 75 | 615 | 70 | 780 | 65 | 1150 | 60 | 1525 | 55 | 1935 | 50 | 2880 | 50 | 4055 |
| 50 | 340 | /50 | 535 | /50 | 745 | /50 | 940 | 50 | 1395 | /50 | 1855 | 50 | 2350 | 50 | 3485 | 50 | 4850 |
| 75 |  | 85 |  | 85 |  | 85 |  | 80\% |  | 70/ |  | 75 |  | $60 /$ |  | 60 |  |
| 60 | 405 | 60 | 620 | 60 | 865 | 60 | 1115 | 60 | 1625 | 60 | 2160 | 60 | 2720 | 60 | 4020 | 60 | 5585 |
| 80/70 | 425 | 100/70 | 700 | 105/70 | 975 | $100 / 70$ | 1255 | 95/70 | 1870 | 85/70 | 2500 | 80/70 | 3195 | 70/70 | 4630 | 70/70 | 6410 |

Note 1. W =whecled vehicles; $\mathrm{T}=$ tracked vehleles.
2. Dual classlification for classes of 30 and above.
3. Scetion modulus in in ${ }^{3}$.

Table 68. Logistical Data and Other Characteristics of Cableways and Tramways

| Type | Issue | Compositiou | Transportation | Capacity | Length | Construction |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | Personnel | Tine |
| Medium cableway--- | Class IV | 2 sectionalized towers <br> 1 carriage <br> 2 keepers <br> 1 drive unit <br> 1 hoist unit <br> Accessories, tools, and tackle. | $42 \frac{1}{2}$-ton trucks or <br> $71 \frac{1}{2}$-ton trucks | Carrier load 3,000 pounds; approximately 17 tons per hour, over 1,000 ft gap. | 1,200 ft-- | 2 platoons- - | 5 hr. |
| Pioneer light aerial tramway and cableway, M1. | Class IV .- | 1 cableway carriage <br> 6 tramway or cableway carriages. <br> 3 tramway carriers ( 7 ft ). <br> 1 drive unit <br> 2 toboggans | $12 \frac{1}{2}$-ton truck or $21 / 2$-ton trucks or <br> 9 1/4-ton trailers or <br> 9 1/4-ton trucks | Tramway-carrier load 350 pounds. Cableway-carrier load 2,000 pounds approximatcly 10 fps. | $2,000 \mathrm{ft}_{\mathrm{L}}$ $1,500 \mathrm{ft}$ | 2 platoons-- | 10 hr. 5 hr. |
| Light aerial tramway, M2 (extension set also available). | Class IV . .- | 1 lower terminal <br> 1 upper terminal <br> 12 intermediate <br> towers. <br> 1 power unit <br> 4 carriers <br> Accessories, tools, and tackle. | 4 21/2-ton trucks <br> or <br> $611 / 2$-ton trucks <br> or <br> $351 / 4$-ton trucks <br> or <br> $351 / 4$-ton trailers | Carrier load 350 pounds approximately 1 ton per hour over 3,000 ft length. | $3,000 \mathrm{ft}^{-}$ | 1 company - | 24 hr. |



```
1. W-Inch coble for trock-eable anchor, (2 parta)
4.Inch coble for houl-rope anchor,(2 parta)
4}\mathrm{ 4nch coble for fall-rope onchor, (2 perts)
M-Inch cobla,(2 parta)
Triple block
Double black
Singla black
Coble orip. wadge type
mynch track cable, &x19, 750 foet
m-meh hout rope, 6x19, :PS
W-inch fall rope, 6x19. IPS
h-inch guy cobla, $x19, IPS, 300 fe9t
```

```
13. #.Inch guy cable, ox19, IPS
H.Inch wadgo tockef, $4-inch J and E rumbuctle
Sreal picket haldfont
Holdfant
H-inch coble sling
Hand-winch onchor orsembly
    Hand winch, S-ton ,
    Wlrerope couplung
    W.nch cable, 6x19, IPS, for adjusting tenzlon in haul rope
3. Stake:
24. #-inch cabla, (2 parts)
```

Figure 20. Medium cableway.


Figure 21. Pioneer tramway.


Figure 22. Pioneer cableway.


Figure 23. Light aerial tramway, M2.

## CHAPTER 7 PONTOON GEAR

## 68. General

The Stcel pontoons uscd consist of hollow stcel boxes, designed to be asscmbled into floating structures of various sizes, shapes, and typcs. Full details are contained in Pontoon Gear Handbook, Navdocks TP-PL-7, Dcpartment of the Navy, Burcau of Yards and Docks.

## 69. Pontoons and Accessories

a. General. There are four types of pontoons, illustrated in figure 24 and described in $b$ through $e$ bclow.
b. The T6B or Rectangular Pontoon. 'The T6B is 5 fcet $1 / 2$ inch by 7 feet in deck area and 5 feet $1 / 2$ inch decp. The side, end, deck, and bilge plating is $3 / 16$ inch thick. The deck is of chcekered plate. Four 2 -inch-diameter plugged holes are provided ncar the corners on one side plate for air, sea cocks, drain, or siphon connection. The pontoon weighs 2,000 pounds and has a volume of 175 cubic feet.
c. The T7A or Curved-Bilge Pontoon. The T7A has the same depth as the $T 6 \mathrm{~B}$, but it has a curved bilge and its deck is 7 fcet square. The side, deck, and cnd plates are $3_{16}^{3 /}$ inch thick; the bilgc plating is $3 / 8$ inch thick. The deck is of checkered platc. Four 2-inch-dianneter plugged holes are provided in the side platc (the plate opposite the curved end). It is used for the curved bow and stern of barges. It wcighs 2,800 pounds and has a volume of 189 cubic fcct.
d. The $T 8$ or Sloped-Deck Pontoon. The T8 is 5 feet $2 \frac{3 / 8}{}$ inches by 7 feet in deck area and is inclined. The depth is 4 feet $11 \frac{3}{8}$ inches at one end and 3 fcet 6 inches at the other. The bottom is horizontal. All the plating is $3 / 16$ inch thick. The dock is checkercd. There are two 2-inch-diametcr plugged holes in the decp end.
e. The T11 or Ramp-End Pontoon. The T11 has the same inclineddcck area as the T8. The offshore end is 3 feet 6 inches deep; the inshore end 1 foot. The bottom is horizontal for the first 1 foot 8 inches; and then pitches upward. The deck is $3 / 16$ inch checkered steel plate, the side and end plates $3 / 16$ inch plain, the bilge plating $3 / 8$ inch plain. The front vertical cdges should be protectcd by welding on fenders consisting of half-sections of 6 -inch steel pipe. There are two 2 -inch-diameter plugged holes in the deep end.


Figure 24. U.S. Navy pontoons.
f. Assembly Angles. The three standard sizes of steel assembly angles are 6 by 6 by $3 / 8$ inches, 6 by 6 by $1 / 2$ inches, and 8 by 8 by $1 / 2$ inches. In assembling pontoons, the size of angle used depends on the nature and size of the assembly and the rigidity required. The angles are fitted with wedge bars, to which the pontoons are attached by the jewelry, and with $1 / 8$-turn breech-plug-slice end couplings for great lengths of assembly. Assembly angles can be altered by cutting and welding but cannot be improvised in the field because of the accuracy required in the spacing of the wedge bars.
g. Sets. The pontoons, assembly angles, jewelry, and other accessories and special parts are made up and shipped in standard sets for field assembly into barges, floating bridges, causeways, floating wharves, drydocks, and other structures.

## 70. Pontoon Assemblies (General)

The standard sets of pontoons and accessories can be assembled into floating units of various types and sizes. These include barges, floating bridges, causeways, floating wharves, drydocks, and other
structures. The practicability of any proposed assembly can be determined by making a parts list of the units needed and comparing it with the packing lists for standard sets as given in the Pontoon Gear Handbook.

## 71. Barges

a. Use. Pontoon barges can be used in a variety of situations as substitutes for ordinary rigid barges. They can also be equipped for use as crancs, piledrivers, drill rigs, and other special-purpose floating plant. If equipped with special inboard or outboard propulsion units, they can be used for icebreakers or tugboats.
b. Assembling. Normally, a string of pontoons of a length depending on the desired length of the barge is first assembled and launched. T7A pontoons are used for the ends and T6B for the rest of the string (fig. 25). Other strings are similarly assembled and launched, and the strings are then connected side by side to give a barge of the desired width. Assembly is by link-and-pin connection at the top angles and by tie rods near the bottom, as shown in figure 26. Installation of A13 deck-closure channels ( 8 -inch ship channel, 18.7 pounds, 5 feet $10 \frac{3}{4}$ inches long) as shown in figure 27 completes the assembly for standard purposes. Figure 27 also shows the method of determining the precise length of a string. Accessories to permit other types of closure and also cleats, chocks, bollards, bits, etc., are available in the standard sets.


Figure 25. Side elevations of barge strings.


Figure 26. Lateral assembly of barge strings.


Figure 27. Deck-closure channels; determining length of string.
c. Buoyancy and Capacity. Pontoon barges up to 6 by 18, about 43 feet by 107 feet and rated at 250 tons with 48 -inch draft, are designed to carry a load at the center point heavy enough to bring the deck awash. For longer barges, the maximum load the barge can float must be distributed over at least the center 6 pontoons of a 24-long barge and at least the center 12 pontoons of a 30 -long floating structure. Table 69 shows the load capacities, in tons, of certain standard barge assemblies.

Table 69. Standard Barge Assemblies

| Number of pontoons wide $\times$ long | Capacity (tons) | Nominal width and length (feet) | Draft |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | Light (inches) | Loaded (inches) |
| $3 \times 7$ | 50 |  | 20 | 48 |
| $4 \times 12$ | 100 | $28 \times 72-\ldots-$---------- | 20 | 44 |
| $5 \times 12$ | 125 | $35 \times 72$ | 20 | 48 |
| $6 \times 18$ | 250 | $43 \times 107$-------------- | 20 | 48 |
| $6 \times 30$ | 500 |  | 20 | 48 |

## 72. Bridges

a. Standard Bridge Units. The term "standard bridge unit" is normally applied by the Navy to an assembly of pontoons used to eonncet a floating pontoon wharf to the shore. Sueh units may also be used to bridge a waterway. The standard units are:
(1) The 2 -by- 12 bridge unit, eomposed of 2 strings each containing' 10 intermediate T 6 B and 2 end T 7 A pontoons.
(2) The 4-by-18 bridge unit, eomposed of 4 strings each eontain$\therefore$ ing 16 intermediate T 6 B and 2 end T7A pontoons.
b. Bridge Strings. Strings of pontoons, known as bridge strings, are also used to bridge a waterway. Normally they are made of T6B pontoons. Figure 28 shows the side elevations of sueh bridge strings. Any desired width ean be attained by assembling strings laterally.
c. Bridging a Waterway. The strings or units used for this purpose are assembled, launehed, and floated into position. The bridge must be anehored and the approaehes prepared, as in the case of Army pontoon equipment. Anehors are not provided with the standard sets. T8 and T11 pointoons may be used at the shore ends. To adjust the length of unit assemblies to the width of the river, strings or units may be lapped in midstream, eare being taken to make the lap long enough for vehieles to negotiate (figs. 29 and 30 ). Aeting as a beam, a 2-by-12 pontoon bridge, supported only at each end, will earry a 40 -ton vehiele at its eenter.


Figure 28. Side elevations of bridge strings.


Figure 29. A bridge made of standard 2 by 12 units, lapped in midstream.

## 73. Standard Causeway

This assembly, made like a 2-by-30 barge, about 14 feet by 175 feet, is side-carried on LST's and launched to permit dry landings on flat beaches. The causeway units ean be assembled later for other bridge, wharf, or barge purposes. End pontoons are T11.

## 74. Wharves

a. The standard sizes are 5 by 12 , about 36 by 70 feet, and 7 by 60 , about 50 feet by 350 feet. All pontoons are T6B.
$b$. Wharves 6 or more pontoons wide and 72 pontoons long, about 43 feet wide by 420 feet long, have been used satisfactorily for unloading cargo ships of Victory and Liberty type (fig. 31). To have adequate depth alongside, they must normally be moored offshore and fitted with bridge approaches. Three approaehes, each 4 pontoons wide, are usually adequate.
c. In proteeted water with depths and bottom materials suitable for pile dolphins, there is no structural limitation on the size of either marginal or finger-pier floating wharves. Satisfactory moorings for sueh wharves have been developed by omitting one T6B pontoon at each corner and at intervals along the face and driving a pile eluster in eaeh of the openings thus provided. The pile elusters also serve as ship moorings and as fenders to hold hulls away from the wharf.


Figure 30. Bridge-to-bridge connection.


Figure 31. A 7-by-72 floating wharf, showing typical moorings.

## CHAPTER 8 UTILITIES

## Section I. WATER SUPPLY AND DISTRIBUTION

## 75. General

The water requircments of troops under various service conditions and the capacities of water-supply and distribution equipment are given in FM 101-10. Related publications dealing with specialized aspects of the problem are TM 5-295 and TM 5-297.

## 76. Responsibilities.

a. Unit Commander. It is the responsibility of the unit commander to provide units and individuals of his command with the required amount of safe drinking water at all times. He must make clear to every individual the danger in drinking unsafe water. He must enforee strict watcr discipline so that men-
(1) Drink only treated or approved water.
(2) Don't waste purified water.
(3) Protect sources of water by good sanitary diseipline.
b. Corps of Engineers. The Corps of Engineers is responsible for making available a supply of approved water for all purposes to all Army units. It is responsible for the design, procurement, installation, operation, and maintenance of water-supply equipment. In addition, it makes reconnaissanecs, develops sources, and transports water to distribution points. It works elosely with the Army Medical Scrvice to make certain that the water is safe to use.
c. Army Medical Service. The Army Medieal Service determines whether or not the water is safe and makes recommendations to the proper authorities. The Army Medical Service inspects the water. points and sourees, tests the water, and works closely with the Corps of Engineers to make ecrtain that the water is treated and distributed properly. In addition, the Army Medieal Service studies and makes recommendations on the design and selection of water-purification equipment.
d. Chemical Corps. The Chemical Corps has responsibilities with respeet to water-supply systems which have been contaminated by toxic agents.

## 77. Water Sources

When the sourees of water in an area are frec of unusual impurities, the following guide the selection of the source.
$a$. In populated areas, use established publie systems to the fullest extent.
$b$. Use existing springs or wells next. The quality of water from these sourees is usually better than from surface sources.
c. If publie or ground-water sourees are not readily available, use surfaee-water sourees such as rivers, streams, lakes, or ponds, ineluding flowing subsurface water in dry streambeds.
$d$. When other sourees are not available, develop ground-water sources. Development of new ground-water sourees is not practicable for an army on the move. For rear-echelon units, a ground-water souree is sually best, especially in areas where surface-water sourecs are highly eontaminated.
$e$. When no fresh-water source ean be found, and sea water is available, use distillation units to purify the sea water.
$f$. In Aretie areas melt snow or iee to obtain water.
$g$. In general, every water souree used by troops must be initially and periodically ehecked for contamination.

## 78. Water Consumption

Table 70 shows approximate figures for per-eapita water demand by troops in a theater under various eonditions. The figures are subject to considerable variation beeause of climate, terrain, physieal condition of troops, water discipline, and other factors.

## 79. Measurement of Flow

a. Stream Flow. $Q=a v$, where $Q$ is quantity of water in eubie feet per second, $a$ is area of cross seetion of stream in square feet, and $v$ is average velocity of stream in feet per second. Determine $a$ by estimate or measurement. Estimate $v$ by measuring the velocity of a ehip floating in midstream and multiplying this by 0.75 .
b. Springs. Note the time required to fill a container of known eapacity.
c. Wells. Pump the well at a rate nearly equal to the rate of flow into the well. Measure the amount obtained by flowing into a suitable vessel or compute the rate of flow by the use of figure 33 or 34 .
d. Free-Flowing Artesian Wells. If the well discharges through a vertieal pipe, measure the height of the jet and apply this measurement to figure 32.

Table 70. Daily Water Requirements

| Unit consumer | Conditions of use | Gallons per unit consumer per day | Remarks |
| :---: | :---: | :---: | :---: |
| Man. | In combat: <br> Minimum <br> Normal | 1/2-1-------- | For periods not exceeding 3 days, when operational rations are used. |
|  |  | 2---------- | When field rations are used. <br> Drinking plus small amount for cooking or personal hygiene. |
|  |  | 3--------- |  |
|  | March or bivouac - <br> Standard 4 and 5 _- | 2-------.-- | Minimum for all purposes. <br> Desirable for all purposes (does not include bathing). |
|  |  | 5---------- |  |
|  | Standard 4 and 5.- <br> Standard 6 |  |  |
|  |  |  | Includes allowance for waterborne sewage system. |
|  | Permanent campMinimum |  |  |
| Horse or mule - |  |  | A horse can go for 48 hr. without water, drinks from 3 to 5 gals. at a watering, and requires 5 min . to drink. |
|  | Normal | $10$ |  |
| Vehicle. | Level and rolling country. <br> Mountainous country. |  | Depending on size of vehicle. <br> Depending on size of vehicle. |
|  |  |  |  |
| Locomotive |  | Variable Variable | 150 gal. per trail mile. 200 gal. per trail mile. Includes water for medical personnel. |
| Hospital | With water-borne sewage. | 50 per bed-- |  |

e. Rate of Flow in Full-Flowing Horizontal Pipe. To determine the rate of flow (in gallons per minute) from full-flowing horizontal pipes, use the formula illustrated in figure 33.
f. Discharge From Partially Filled Horizontal Pipe. To determine the rate of flow (in gallons per minute) from partially filled pipes divide the height of the fluid in the pipe ( K , in inehes) by the diameter ( D , in inches). If $K / D$ is between 0.2 and 0.6 , apply the value to the alignment chart (fig. 34).
80. Pressure and Discharge Tables


FLOW FROM PIPE IN GALLONS PER MINUTE
Figure 32. Flow from artesian well-vertical well pipe.


Figure 33. Flow from full-flowing horizontal pipe.


Figure 34. Flow from partially filled horizontal pipe; good for $K / D$ values between 0.2 and 0.6 .

Table 71. Flow of Water (Gallons Per Minute) Through Smooth-Bore Hose ${ }^{1}$

| Hose <br> $\begin{array}{c}\text { (internal } \\ \text { diameter } \\ \text { inehes) }\end{array}$ | Water pressure, pounds per square ineh |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 125 |
| 1.00 | 23 | 28 | 33 | 37 | 40 | 43 | 46 | 49 | 52 | 58 |
| 1.25 | 40 | 50 | 57 | 64 | 70 | 76 | 81 | 86 | 90 | 101 |
| 1.50 | 64 | 78 | 90 | 101 | 111 | 120 | 128 | 135 | 143 | 159 |
| 2.00 | 130 | 159 | 184 | 206 | 227 | 242 | 262 | 275 | 292 | 326 |
| 2.50 | 226 | 278 | 322 | 358 | 394 | 425 | 455 | 482 | 509 | 566 |
| 3.00 | 356 | 437 | 504 | 570 | 620 | 665 | 715 | 755 | 800 | 890 |
| 4.00 | 745 | 910 | 1, 055 | 1, 180 | 1, 292 | 1,395 | 1, 492 | 1, 582 | 1, 670 | 1,850 |

1 Data shown are based on 100 -foot length of hose, laid in a straght line with open diseharge end. For each set of eouplings, deduet 5 pereent.

Table 72. Suction Lifl of Pumps al Various Allitudes

| Altitude above sea level |  |  | Barometric pressure (pounds per square inch) | Equivalent head of water (feet) | Praetieal suetion lift of pump (feet) |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Fect | Miles |  |  |  |
| 0 |  | 0 | 14. 70 | 33. 95 | 25 |
| 1,320 |  | 1/4 | 14.02 | 32. 38 | 24 |
| 2.640 |  | 1/2 | 13. 33 | 30. 79 | 23 |
| 3,960 |  | $3 / 4$ | 12. 66 | 29. 24 | 21 |
| 5,280. |  | 1 | 12. 02 | 27. 76 | 20 |
| 6,600. |  | 11/4 | 11. 42 | 26. 38 | 19 |
| 7,920. |  | 11/2 | 10.88 | 25. 13 | 18 |
| 10,560 |  | 2 | 9.88 | 22. 82 | 17 |

Table 79. Theoretical Discharge of Nozzles in Uniled States, Gallons Per Minute ${ }^{1}$


The actual quantlics will vary from the figures in this table, depending on the shape With smooth-taper nozzles the actual diseharge is about 94 pereent of the figures glven of the nozzle and the size of the pipe at the point where the pressure is determined. in the table above.

Table 74. Maximum Quantities of Water in Gallons Per Minute Which Can Be Pumped Through 100 Feet of Wrought-Iron Pipe at Various Pressures

| Pressure | Pipe dameter (inches) |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 3/2 | $3 / 4$ | 1 | $14 / 4$ | 11/2 | 2 | 236 | 3 | 4 |
| 17 psi | 3. 2 | 9. 1 | 18.7 | 33.5 | 51.6 | 106 | 200 | 290 | 589 |
| 30 psi . | 5. 0 | 14.0 | 28.0 | 52.0 | 78. 0 | 160 | 308 | 436 | 885 |
| 40 psi | 6. 0 | 16. 0 | 33.0 | 60.0 | 90.0 | 184 | 350 | 504 | 1, 023 |
| 50 psi | 6.5 | 17.5 | 37.0 | 70.0 | 101. 0 | 206 | 390 | 564 | 1, 143 |
| 60 psi | 7. 0 | 19.5 | 40.0 | 76.0 | 110.0 | 226 | 430 | 617 | 1, 252 |
| 75 psi. | 7. 5 | 22.0 | 45. 0 | 85.0 | 123. 0 | 253 | 480 | 690 | 1, 400 |
| 100 psi | 9. 0 | 25. 0 | 52.0 | 99.0 | 142. 0 | 292 | 558 | 797 | 1, 607 |



Table 75. Relative Equivalent Quantilies of Water Delivered

| Gallons in 1 iminute | Gallons in I hour | Gallons in 24 hours | Gallons in 1 minute | Gallons in 1 hour: | Gallons in 24 hours | Gallons 111 1 minute | Gallons in $1 \text { hour }$ | Gallons in 24 hours |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 3. 4 | 208 | 5, 000 | 138.8 | 8,333 | 200, 000 | 486.1 | 29, 166 | 700, 000 |
| 6. 9 | 416 | 10, 000 | 173.6 | 10,416 | 250, 000 | 520.8 | 31, 250 | 750, 000 |
| 10. 4 | 625 | 15, 000 | 208.3 | 12. 500 | 300, 000 | 555.5 | 33, 333 | 800,000 |
| 13.8 | 833 | 20, 000 | 243.0 | 14, 583 | 350, 000 | 590.2 | 35, 416 | 850,000 |
| 17.3 | 1,041 | 25, 000 | 277.7 | 16, 666 | 400, 000 | 625.0 | 37, 500 | 900, 000 |
| 34.7 | 2, 083 | 50, 000 | 312.5 | 18,750 | 450, 000 | 659.7 | 39,583 | 950, 000 |
| 41.6 | 2, 500 | 60, 000 | 347.2 | 20, 833 | 500, 000 | 694.3 | 41,666 | 1,000,000 |
| 52.9 | 3, 125 | 75, 000 | 381.9 | 22, 916 | 550, 000 | 1,041. 7 | 62, 500 | 1,500, 000 |
| 69.4 | 4, 166 | 100, 000 | 416.7 | 25, 000 | 600, 000 | 1,388. 0 | 83, 333 | 2, 000, 000 |
| 104. 1 | 6, 250 | 150, 000 | 451.3 | 27, 083 | 650, 000 | 1,736. 0 | 104, 166 | 2, 500, 000 |

## 81. Rate of Flow Equivalents

See table 76.

## 82. Volume and Capacity Equivalents

See table 77.

## 83. Head-Pressure Conversion Factors

The head of water in fect and the resultant static pressure in p.s.i. (pounds per square inch) are related as follows:

Pressure $=$ head $>0.4331$
Head $=$ pressure $\times 2.31$.

## 84. Loss of Head in $11 / 2$-Inch Hose

For various flows in gallons per minute, the loss of head per hundred feet of $1 \frac{1}{2}$-inch hose is given in figure 35 .


Figure 35. Loss of head in $1 \frac{1}{2}$-inch hose.

Table 76. Rate of Flow Equivalents

| Units | Cubic feet per second | Cubic feet per minute | U.S. gallons per minute | U.S. gallons per 24 hr . |
| :---: | :---: | :---: | :---: | :---: |
| 1 cubic foot per second equals | 1. 0 | 60.0 | 448. 83 |  |
| 1 cubic foot per minute equals $\qquad$ | 0. 02 | $\text { 1. } 0$ | 7. 48 | 10,771.9 |
| 1 U.S. gallon per minute equals | $0.002$ | $0.13$ | 1. 0 | 1, 440.0 |
| 1 U.S. gallon per 24 hours equals | $1.55 \times 10^{-}$ | $9.28 \times 10^{-5}$ | $0.0007$ | 1. 0 |
| 1 British Imperial gallon per minute equals. | $0.003$ | $0.16$ | 1. 20 | 1, 729.37 |
| 1 liter per minute equals.-- | 0. 0006 | 0. 03 | 0. 26 | 380.42 |
| 1 acre-foot per hour equals. | 12. 1 | 726. 0 | $5,430.86$ | 7, 820, 434. 0 |
| 1 acre-foot per 24 hours equals. | $0.50$ | $30.25$ | 226. 2 | 325, 851. 0 |
|  |  |  |  |  |
| Units | British Imperial gallons per minute | Liters per minute | Acre-fcet per hour | Acre-fect per 24 hr . |
| 1 cubic foot per second equals. | 373. 3 | 1, 698. 98 | 0. 083 | 1. 98 |
| 1 cubic foot per minute equals. | 6. 23 | 28. 32 | 0. 001 | 0. 03 |
| 1 U.S. gallon per minute equals | 0. 83 | 3. 78533 | 0. 0001841 | 0. 0044192 . |
| 1 U.S. gallon per 24 hours equals | 0. 000 | 0.003 | 1. $28 \times 10^{-7}$ | $3.07 \times 10^{-5}$ |
| 1 British Imperial gallon per minute equals. | 1. 0 | 4. 55 | 0. 0002 | 0. 005 |
| 1 liter per minute equals.-- | 0. 22 | 1. 0 | 4. $86 \times 10^{-5}$ | 5.0 .001 |
| 1 acre-foot per hour equals. | 4, 522. 13 | 20,557. 6 | 1. 0 | 24.0 |
| 1 acre-foot per 24 hours equals. | 188. 42 | 856.57 | 0. 04 | 1. 0 |

Note. Negative exponents to the number 10 indicate the number of decimal places to the right of the decimal point, i.e.: $10^{-6}=0.000001 ; 10^{-3}=0.001 ; 1.55 \times 10^{-6}=0.00000155$.

Table 77. Volume and Capacily Equivalents

| Unlts | U.S. gallons | Britlsh Imperial gallons | Liters |
| :---: | :---: | :---: | :---: |
| 1 U.S. gallon equals - | 1. 0 | 0. 83 | 3. 78 |
| 1 British Imperial gallon equals. | 1. 20 | 1. 0 | 4. 55 |
| 1 liter equals . . . | 0. 26 | 0. 22 | 1. 0 |
| 1 cubic foot equals | 7. 48 | 6. 23 | 28.32 |
| 1 cubic inch equals . - | 4. 33 | 3. $6 \times 10^{-3}$ | 0. 02 |
| 1 acre-foot equals . .-- | 325851. 0 | 271, 328. 0 | 1, 233, 456. 0 |
| 1 inch deep on 1 acre equals. | 27154. 3 | 22,610. 6 | 102, 788. 0 |
| 1 inch deep on 1 square mile equals.- | 17, 378, 743. 0 | $14,470,801.0$ | 65, 784, 344. 0 |
| 1 meter deep on 1 <br> hectare equals. | 2, 641, 705. 0 | 2, 199, 675. 0 | 9, 999, 734. 0 |
| 1 centimeter deep on 1 square meter equals. $\qquad$ | 2. 64 | 2. 20 | 10.0 |
| 1 pound of water at $39.2^{\circ} \mathrm{F}$. equals. | 0. 02 | 0. 10 | 0. 45 |
| 1 pound of water at $50^{\circ} \mathrm{F}$. equals | 0.12 | 0. 10 | 0. 45 |
| 1 pound of water at $62^{\circ} \mathrm{F}$. equals. $\qquad$ | 0. 12 | 0. 10 | 0. 45 |
| 1 U.S. gallon per minute for 24 hours equals $\qquad$ | 1, 440. 0 | 1, 199. 05 | 5, 450. 88 |
| 1 cubic foot per minute for 24 hours equals $\qquad$ | 10,771.9 | 8, 969. 50 | 40, 775. 4 |

See note at end of table.

Table 77. Volume and Capacity Equivalents-Continued

| Units | Cublc feet | Cubic inches | Acre-fect |
| :---: | :---: | :---: | :---: |
| 1 U.S. gallon equals . .-- | 0. 13 | 231. 0 | 3. $07 \times 10^{-6}$ |
| 1 British Imperial gal- |  |  |  |
| lon equals_-.-.------ | 0. 16 | 277. 42 | 3. $69 \times 10^{-6}$ |
| 1 liter equals $-\ldots-\ldots-{ }^{\text {- }}$ | 0. 03 | 61. 02 | $8.11 \times 10^{-7}$ |
| 1 cubic foot equals .-.-- | 1. 0 | 1, 728. 0 | 2. $296 \times 10^{-5}$ |
| 1 cubic inch equals....- | 5. $79 \times 10$ | 1. 0 | 1. $33 \times 10^{-8}$ |
| 1 acre-foot equals.-...- | 43, 560. 0 | 75, 271, 680. 0 | 1. 0 |
| 1 inch deep on 1 acre equals. $\qquad$ | 3, 630. 0 | 6, 272, 640.0 | 0. 08 |
| 1 inch deep on 1 square mile equals. | 2, 323, 200. 0 | $4,014,489,600.0$ | 53. 33 |
| 1 meter deep on 1 hectare equals | 353, 145. 0 | 610, 233, 780. 0 | 8. 10708 |
| 1 centimeter deep on 1 square meter equals | 0. 35 | 610. 23 | 8. $11 \times 10^{-6}$ |
| 1 pound of water at $39.2^{\circ} \mathrm{F}$. equals | 0.02 | 27.68 | $3.69 \times 10^{-7}$ |
| 1 pound of water at $50^{\circ}$ <br> F. equals $\qquad$ | 0. 02 | 27. 69 | $3.68 \times 10^{-7}$ |
| 1 pound of water at $62^{\circ}$ <br> F. equals $\qquad$ | 0.02 | 27. 71 | 3. $68 \times 10^{-7}$ |
| 1 U.S. gallon per minute for 24 hours equals. | 192. 5 | 332, 640. 0 | 0. 004 |
| 1 cubic foot per minute for 24 hours equals. | 1. 440.0 | 2, 488, 320.0 | 0.03 |

Note. Negative exponents to the number 10 indicate the number of decimal places to the rigbt of the decimal point, i.e.: $10^{-6}=0.000001 ; 10^{-3}=0.001 ; 1.55 \times 10^{-6}=0.00000153$.

## 85. Vertical Cylindrical Tank Capacities

Capacitics per foot of depth for vertieal cylindrical tanks 1 foot to 100 feet in diamcter are shown in table 78. Capacities per inch of depth may be computed by dividing the values shown by 12 .

## 86. Chemicals Used to Coagulate or Adjust Alkalinity of Water

 See table 79.
## 87. Water Supply and Distribution Systems

a. Function. A water system consists of a well, spring, river, lake, reservoir, or other water source; the treatment plant, pump, ground or elevated storage tanks, supply lines, or other production and treatment facilities; and the distribution lincs whieh convey the approved water to the various outlets.
b. Description.
(1) Basic systems. There are three basic types of water supply and distribution systems.
(a) Gravity flow, wherc the source is at sufficient clevation above the outlets to transport the water without pumping.

Table 78. Vertical Cylindrical Tank Capacitips

| Diameter | Cu ft per $1^{\prime}$ of depth | U.S. gallons per 1' of depth | Diameter | Cuft per $1^{\prime}$ of depth | U.S. gallons per $1^{\prime}$ of depth |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $1^{\prime} \quad 0^{\prime \prime}$ | 0. 785 | 5. 87 | $4^{\prime} \quad 4^{\prime \prime}$ | 14. 75 | 110. 3 |
| $1^{\prime} 1^{\prime \prime}$ | 0. 922 | 6. 89 | $4^{\prime} 5^{\prime \prime}$ | 15. 32 | 114. 6 |
| $1^{\prime} 2^{\prime \prime}$ | 1. 069 | 8. 00 | $4^{\prime} 6^{\prime \prime}$ | 15. 90 | 119.0 |
| $1^{\prime} 3^{\prime \prime}$ | 1. 227 | 9. 18 | $4^{\prime} \quad 7^{\prime \prime}$ | 16. 50 | 123. 4 |
| $1^{\prime} \quad 4^{\prime \prime}$ | 1. 396 | 10. 44 | $4^{\prime} \quad 8^{\prime \prime}$ | 17. 10 | 128. 0 |
| $1^{\prime} 5^{\prime \prime}$ | 1. 576 | 11. 79 | $4^{\prime} \quad 9^{\prime \prime}$ | 17. 72 | 132. 6 |
| $1^{\prime} 6^{\prime \prime}$ | 1. 767 | 13. 22 | $4^{\prime} 10^{\prime \prime}$ | 18. 35 | 137. 3 |
| $1^{\prime} 7^{\prime \prime}$ | 1. 969 | 14. 73 | $4^{\prime} 11{ }^{\prime \prime}$ | 18. 99 | 142. 0 |
| $1^{\prime} 8^{\prime \prime}$ | 2. 182 | 16. 32 | $5^{\prime}$ | 19.63 | 146. 9 |
| $1^{\prime} 9^{\prime \prime}$ | 2. 405 | 17. 99 | $5^{\prime} 3^{\prime \prime}$ | 21. 65 | 161.9 |
| $1^{\prime} 10^{\prime \prime}$ | 2. 640 | 19. 75 | $5^{\prime} 6^{\prime \prime}$ | 23. 76 | 177. 7 |
| $1^{\prime} 11^{\prime \prime}$ | 2. 885 | 21. 58 | $5^{\prime} 9^{\prime \prime}$ | 25. 97 | 94.3 |
| $2^{\prime}$ | 3. 142 | 23. 50 | $6^{\prime}$ | 28. 27 | 211.5 |
| $2^{\prime} 1^{\prime \prime}$ | 3. 409 | 25. 50 | $6^{\prime} 3^{\prime \prime}$ | 30. 68 | 229. 5 |
| $2^{\prime} 2^{\prime \prime}$ | 3. 687 | 27. 58 | $6^{\prime} 6^{\prime \prime}$ | 33. 18 | 248. 2 |
| $2^{\prime} 3^{\prime \prime}$ | 3. 976 | 29. 74 | $6^{\prime} 9^{\prime \prime}$ | 35. 78 | 267. 7 |
| $2^{\prime} 4^{\prime \prime}$ | 4. 276 | 31. 99 | $7{ }^{\prime}$ | 38. 48 | 287. 9 |
| $2^{\prime} 5^{\prime \prime}$ | 4. 587 | 34. 31 | $7^{\prime} 3^{\prime \prime}$ | 41. 28 | 308. 8 |
| $2^{\prime} 6^{\prime \prime}$ | 4. 909 | 36. 72 | $7^{\prime} 6^{\prime \prime}$ | 44. 18 | 330.5 |
| $2^{\prime} 7^{\prime \prime}$ | 5. 241 | 39. 21 | $7^{\prime} 9^{\prime \prime}$ | 47. 17 | 352. 9 |
| $2^{\prime} 8^{\prime \prime}$ | 5. 585 | 41. 78 | $8^{\prime}$ | 50. 27 | 376.0 |
| $2^{\prime} 9^{\prime \prime}$ | 5. 940 | 44. 43 | $8^{\prime} 3^{\prime \prime}$ | 53. 46 | 399.9 |
| $2^{\prime} 10^{\prime \prime}$ | 6. 305 | 47. 16 | $8^{\prime} 6^{\prime \prime}$ | 56. 75 | 424. 5 |
| $2^{\prime} 11^{\prime \prime}$ | 6. 681 | 49. 98 | $8^{\prime} \quad 9^{\prime \prime}$ | 60. 13 | 449. 8 |
| $3^{\prime}$ | 7. 069 | 52. 88 | $9^{\prime}$ | 63. 62 | 475.9 |
| $3^{\prime} 1^{\prime \prime}$ | 7. 467 | 55. 86 | $9^{\prime} \quad 3{ }^{\prime \prime}$ | 67. 62 | 502. 7 |
| $3^{\prime} 2^{\prime \prime}$ | 7. 867 | 58. 92 | $9^{\prime} 6^{\prime \prime}$ | 70. 88 | 530. 2 |
| $3^{\prime} 3^{\prime \prime}$ | 8. 296 | 62.06 | $9^{\prime} \quad 9^{\prime \prime}$ | 74. 66 | 558. 5 |
| $3^{\prime} 4^{\prime \prime}$ | 8. 727 | 65. 28 | $10^{\prime}$ | 78. 54 | 587.5 |
| $3^{\prime} 5^{\prime \prime}$ | 9. 168 | 68. 58 | $10^{\prime} 6^{\prime \prime}$ | 86. 59 | 647.7 |
| $3^{\prime} 6^{\prime \prime}$ | 9. 621 | 71. 97 | $11^{\prime}$ | 95. 03 | 710. 9 |
| $3^{\prime} 7^{\prime \prime}$ | 10.08 | 75. 44 | $11^{\prime} 6^{\prime \prime}$ | 103. 9 | 777.0 |
| $3^{\prime} \quad 8^{\prime \prime}$ | 10. 56 | 78. 99 | $12^{\prime}$ | 113. 1 | 846. 0 |
| $3^{\prime} 9^{\prime \prime}$ | 11. 04 | 82. 62 | $12^{\prime} 6^{\prime \prime}$ | 122. 7 | 918. 0 |
| $3^{\prime} 10^{\prime \prime}$ | 11. 54 | 86. 33 | $13^{\prime}$ | 132. 7 | 992.9 |
| $3^{\prime} 11^{\prime \prime}$ | 12. 05 | 90. 13 | $13^{\prime} 6^{\prime \prime}$ | 143. 1 | 1, 071.0 |
| $4^{\prime}$ | 12. 57 | 94. 00 | $14^{\prime}$ | 153. 9 | 1, 152. 0 |
| $4^{\prime} \quad 1^{\prime \prime}$ | 13. 10 | 97. 96 | $14^{\prime} 6^{\prime \prime}$ | 165. 1 | 1, 235. 0 |
| $4^{\prime} \quad 2^{\prime \prime}$ | 13. 64 | 102. 0 | $15^{\prime}$ | 176. 7 | 1,322. 0 |
| $4^{\prime} \quad 3^{\prime \prime}$ | 14. 19 | 106. 1 | $15^{\prime} 6^{\prime \prime}$ | 188. 7 | 1, 412.0 |

Table 78. Vertical Cylindrical Tank Capacities-Continued


Table 79．Chemicals Used to Coagulate or Adjusi Alkalinity of Water

| Chemical | How to usc | How shipped | Weight （pounds per cuble foot） | Effective pH range | Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant | Artificial alkalinity re－ quircd in grains per gallon to react with 1 grain per gallon of co－ agulant |  |  | Remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | Hydrated lime | Quick－ lime | Soda ash |  |
| $\begin{aligned} & \text { Alum- } \mathrm{Al}_{2}\left(\mathrm{SO}_{4}\right)_{3} \\ & 18 \mathrm{H}_{2} \mathrm{O} . \end{aligned}$ | Coagulant．－．－．－－－－ | 100－pound bags 200－pound bags． 400－pound barrels． Bulk． | ＇39．－ | $\begin{aligned} & 4.4 \text { to } 6.0 . \\ & 5.7 \text { to } 8.0 \\ & 9.0 \text { to } 10.5 \end{aligned}$ | 0.45 | 0.35 | 0.28 | 0.48 | 4.4 to 6.0 pH range used for highly colored water． 5.7 to 8.0 pH range used for turbid and moderately colored water． 9.0 to 10.5 pH range used in alum co－ agulation of carbonates in lime－soda softenlng． |
| $\begin{aligned} & \text { Ammonta alum- } \\ & \mathrm{Al}_{2}\left(\mathrm{SO}_{4}\right)_{3} \\ & \left(\mathrm{NH}_{4}\right)_{2} \mathrm{SO}_{4} . \\ & 24 \mathrm{H}_{2} \mathrm{O} . \end{aligned}$ | Coagulant．－．－．－－－－ | 400－pound bags．－－－．－． <br> 100－pound kegs． | 39土－－－－－－－－ | 5.7 to 8．0．－ | $0.29 \pm$ | 0．23土 | 0．18士 | 0．31土 | Less soluble than filter alum and welghs 11,2 times as much in terms of aluminum oxide content．Use generally restricted to pressure filters incorporating an＂alum pot＂or in batch coagulation．Ammo－ nia avallable for formation of choloro－ mines． |
| Sulfurle acld－ $\mathrm{H}_{2} \mathrm{SO}_{4}$ ． | To adjust pII in connection with coagulation． | 10－gallon carboys． 500－pound stecl drums． $93 \%$ ． <br> 1，500－pound stcel $\mathrm{II}_{2} \mathrm{SO}_{4}$ ．drums | Liquid： 18 pounds per gallon． |  |  |  |  |  | Always dilute by adding acld to water， otherwise serious burns may result．Can be fed by usc of hypochlorlte－solution equipment． |

[^20]| Chemical | How to use | How shlpped | Weight (pounds per cubic foot) | Effectlve pll. range | Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant | Artificial alkalinity required ln gralns per gallon to react with 1 grain per gallon of coagulant |  |  | Remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | $\begin{gathered} \text { Hydrated } \\ \text { lime } \end{gathered}$ | Quickllme | Soda ash |  |
| Sodium alumlnate$\mathrm{Na}_{2} \mathrm{Al}_{2} \mathrm{O}_{4}$. | Coagulant...... | Solid: <br> 108-pound thinstecl drums. <br> 405-pound thinsteel drums. <br> 100 -pound bags. <br> Liquld: <br> $32 \% \mathrm{Na}_{2} \mathrm{Al}_{2} \mathrm{O}_{4}-$ steel drums $10 \% \mathrm{NaOH}$. | 58土....-....- | $\begin{aligned} & 6.0 \text { to } 7.5 \\ & \text { (with } \\ & \text { ulum). } \end{aligned}$ |  |  |  |  | Used wlth alum to assist In the eoagulation of eold water. Also used wlth alum to coagulate alkallne waters, such as with water softening. Supplles alkall as well as aluminum. Commerclai grade contalns $55 \%$ aluminum oxide and $35 \%$ comblaed soda plus $6 \%$ exeess eaustle soda. |
| Copperas (ferrous sulfate) $-\mathrm{FeSO}_{4}$. | Coagulant.-- | 100-pound bags...... 200-pound bags. 400-pound barrels. Bulk. | 46土-----.--- | 8.5 to 11.0 |  | 0.27 | 0. 22 | (1) |  |
| Chlorinated copperas. | Congulant... | Sce copperas. --.--- | SceCopperas | 3.5 to 9.5.. | 0.85 | ${ }^{2} 0.65$ | 0.52 | (1) | Chlorlne added to copperas. One pound of chlorine required for each 7.8 pounds of copperus used. |
| Ferric sullate$\mathrm{Fe}_{2}\left(\mathrm{SO}_{4}\right)_{3}$. | Congulant... | 200-pound bags...-.-. 400 -pound wooden barrels. | 70.---------- | 3.5 to 9.5- | 078 | 058 | 0.46 | (1) | If dry-fect machine is used, must have solution pot feeding two parts water to cach part of ferrle sulfate. Used wlth llme for fron and manganese removal. |


| Ferrie cblordde$\mathrm{FeCl}_{3}$. | Coagulant-........- | Liquld: <br> 12-gallon carboys. $42 \%$. <br> 8,000-gallon rubber-ifined tank ears. $42 \%$. Crystals: <br> 55-galion hardwood barrels, each containing 435 pounds. $60 \%$. <br> Anhydrous: <br> 100 one pound bags per steel drum. $95 \%$ ferric chloride. |  | 3.5 to 9.5.. | 0.92 | 0.72 | 0.58 | (1) | Very corrosive. Rubberlined equipment must be used. Use with lime for iron and manganese removal. Use with puiverized limestone to coagulate turbid and colored waters. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Soda ash $-\mathrm{Na}_{2} \mathrm{CO}_{3}-$. | To adjust pH , aidi coagulation, or remove perma. nent hardness. | 100-pound bags <br> 200-pound bags. <br> 400-pound barrcls. <br> Bulk. | 63. |  |  |  |  |  | Readily soluble and non-corrosive to wrought-iron or lead piping. May be used to prevent corrosion when hardness of water execeds about 40 quarts per milllon. |
| Hydrated lime- $\mathrm{Ca}(\mathrm{OH})_{2}$ | To adjust pII, aid coagulation, or remove carbonate hardness. | 50-pound paper bags. - | 50. |  |  |  |  |  | Only slightly soluble and thus is fed as a suspension. Cheaper and more effective than soda ash. Used to prevent corrosion irrespectlve of bardness of water. |
| Qulck lime-CaO... | To adjust pH , aid coagulation, or remove carbonate hardness. | Wooden barrels, metal drums, water proof bags. <br> Bulk. | 65.... <br> $V$ |  |  |  |  |  | Must be siaked before used. Somewhat eheaper and more effective than hydrated llme, but difficulty of handling limits its used to large plants. |
| Pulverised lime-stone-94\% $\mathrm{CaCO}_{3}$. | Adjust pH and/or aid coaguiation. | 80-pound bags or bulk- | 100. |  |  |  |  |  | May be added as batcb or fed witb dry or slurry feeders. Particularly useful in sollds, contaet reacters. |

[^21](b) Direct pumping, where water from the source is pumped directly into the system with or without a pressure tank to absorb differences between pumping and usage rates.
(c) A combination of gravity and pumping, where water from the source is pumped to an elevated storage tank and from there distributed to the outlets by gravity.
(2) Pipes.
(a) Classification. The network of pipes should be arranged so that large primary mains feed smaller secondary pipes. Mains carry water from the source to the service pipes. Service pipes carry water from the main to the building.
(b) Arrangement. A distribution system is constructed either as a dead-end system or as a loop system. In a dead-end system a single distribution main runs from the pump or elevated storage tank to the various outlets. In a loop system the distribution main forms a single loop or a series of loops with both ends connected to the pump or elevated storage tank. The advantage of a dead-end system is the economy in length of main. The advantages of a loop system are the equal delivery capacity with smaller mains, a more uniform pressure, and the ability to make repairs with a minimum of outlets deactivated. Complete loop systems are seldom used in field installations.
(c) Design and construction. The design of a distribution system is based on the known requirements and physical data obtained from reconnaissance, surveys, and maps. TM 5-302 includes standard layouts.

## 88. Equipment for Purification and Treatment

a. Standard Sets.
(1) The following sets are now standard:
(a) Water purification equipment set, trailer mounted, diatomite filter, 600 gph ; primarily for airborne use.
(b) Water purification equipment set, truck mounted, diatomite filter, $1,500 \mathrm{gph}$; primarily for use with combat units.
(c) Water purification equipment set, truck mounted, diatomite filter, $3,000 \mathrm{gph}$.
(d) Water purification equipment set, base mounted, diatomite filter, $3,000 \mathrm{gph}$; for use as stationary equipment under Arctic conditions, and also in non-Arctic areas.
(2) A water purification plant with a capacity of $10,000 \mathrm{gph}$ is under development at ERDL, and it is expected will shortly become standard. It incorporates coagulation and rapid sand filtration apparatus.
b. Locally Designed Facilities. If standard water purifieation sets are not available or do not meet local requirements, other standard issue pumps are used with issuc or locally designed and constructed storage and treatment facilities. The usual storage requirement is for an aggregate of half a day's supply in reservoirs and/or tanks, normally with at least one tank clevated to insure adcquate head. Treatment facilities depend upon the type and quantity of water but normally inelude the items shown in the typical flow diagram, figure 36 .
c. Typical Equipment for Storage and Treatment.
(1) Pumps.
(a) Centrifugal self priming pumps. The following are now standard:
10 gpm at 80 ft . head, eleetric driven.
50 gpm at 70 ft . head, eleetric driven.
50 gpm at 25 ft . head, gasoline driven.
115 gpm at 25 ft . head, gasoline driven.
166 gpm at 25 ft . hcad, gasoline driven.
200 gpm at 300 ft . head, gasoline driven.
500 gpm at 30 ft . head, gasoline driven.
$1,500 \mathrm{gpm}$ at 60 ft . head, gasoline driven. $2,100 \mathrm{gpm}$ at 25 ft . head, gasoline driven.
(b) Helical rotor type pumps. The standard type is a deep well pump, 50 gpm at 250 ft . head, gasoline driven.
(c) Turbine type pumps. The standard type is a deep well pump, 200 gpm at 200 ft . hcad, gasoline or electric driven.
(d) Diaphragm type pumps. The standard type, preferred for abrasive material, delivers 200 gpm at 10 ft . head, gasoline driven.
(2) Storage tanks. Standard vertieal eylindrical bolted steel tanks, low type, for the storage of water or petroleum produets, are issued in eapacities of $4,200,10,500,21,000$, and 42,000 gallons. For the high type the standard tank has a eapacity of 126,000 gallons. Standard rubber coatcd fabrie tanks are issued in capacities of $500,1,500$, and 3,000 gallons.
(3) Plain sedimentation tanks or basins. (To remove sediment from raw water not coagulated.) A typical shape is shown in figure 37. To determine the sizc needed, assume a depth between 5 and 10 fect, plus 1 foot ( $6^{\prime \prime}$ freeboard and $6^{\prime \prime}$ allowanee for sludge). Find the time (minutes) required for $70 \%$ of the solids to settle from a sample of the water in a bottle. Tank size is then computed from:
(a) $\underset{\text { Retention time }}{\text { (minutes water }}$ must stay in tank) $) ~=\frac{\begin{array}{c}\text { Effective tank } \\ \text { depth (ft.) }\end{array} \times \begin{array}{c}\text { Settling time in } \\ \text { bottlc (min.) }\end{array}}{\text { Depth of water sample in bottle (ft.) }}$


Figure 36. Flow diagram for typical water treatment plant.
(b) Tank capreity $=\frac{\text { Retention time }(\mathrm{min}) \times \text { required flow (gpm) }}{\text { (cu. ft.) }}{ }^{7.5 \text { (gal per cu. ft.) }}$
(c) Tank length (ft.) $=$ Retention time (min) $\times$ velocity of flow ( fpm ) Desirable velocities are between 0.6 and 1.0 ( fpm ).
$\underset{(\mathrm{ft} .)}{\mathrm{Tank} \text { width }}=\frac{\text { Tank eapaeity (eu. ft.) }}{\text { Tank depth (effeetive) (ft.) } \times \text { tank length (ft.) }}$
(e) Example: Given: Required flow, 500 gpm ; settling time in a bottle 6 inehes deep, 5 min:; effeetive tank depth assumed at 5 feet; velocity of flow assumed at 0.9 fpm . Solution:

Retention time $=\frac{5 \times 5}{.5}=50 \mathrm{~min}$.
Tank eapacity $=\frac{50 \times 500}{7.5}=3,333 \mathrm{cu} . \mathrm{ft}$.
Tank length $\quad=50 \times 0.9=45 \mathrm{ft}$.
Tank width $=\frac{3,333}{5 \times 45}=14.8 \mathrm{ft}$. (Use 15 ft .)
(4) Chemical-mixing and coagulation tanks. If the water is easily eoagulated, these are omitted and coagulants are added at the suetion side of the pump supplying a floe sedimentation tank. If a coagulation tank is needed, its eapaeity should be at least 2 to 4 hours of the required flow rate; e.g., 5,000 gallons for a flow rate of 500 gpm . One type of coagulant tank with auxiliary equipment is shown as figure 38.
(5) Floc sedimentation tanks. These are similar to the plain sedimentation tanks described in (3) above and the size is determined in the same way, based on the settling time for a bottle of the coagulated water as it reaches the tank. The size is usually smaller, due to more rapid settling after coagulation. A velocity of flow of 1.0 fpm is usually satisfactory.
(6) Filters. For military installations too large to be served by the standard issue filters, a rapid sand filter is usually satisfactory. These filters are described as follows:
(a) Types and capacity. Rapid sand filters are either gravity or pressure types, as shown in figures 39 and 40. Gravity filters are open steel tanks as shown in figure 41 or may be rectangular reinforeed concrete boxes, operated as shown in figure 41. Pressure filters are inelosed vessels in which water is pumped through the bed of filter sand. Gravity filters are best for large installations; pressure


Figure 37. Settling tank for either plain or coagulated sedimentation.

filters are preferable for filtering small volumes of water beeause only one pump is required and all valves are aecessible. The eapaeity of each type is usually 2 to 3 gpm per square foot of filter bed.
(b) Filter media.

1. Filter sand must be free from elay, loam, lime and organic matter, and with uniform grains of the proper size. For rapid sand filters, the preferred sands as to grain sizes are those whieh have an effeetive grain size between $0.40-$ and $0.60-\mathrm{mm}$, and a uniformity eocfficient lower


Figure 39. Typical gravity filter, showing relationship of filter medium, gravel, and underdrain.


Figure 40. Pressure-type rapid sand filter.
than 1.75. Effective grain size is that grain size in a given sample which is larger than 10 pereent of, but smaller than 90 percent of, the grains in the sample. The uniformity cocfficient is the grain size such that 60 percent of the grains are smaller, divided by the effective size. Thus if 60 pereent of a sample passes a sieve with $0.42-\mathrm{mm}$ openings and 10 percent passes a sieve with $0.15-\mathrm{mm}$ openings, the uniformity coefficient is 0.42 $\div 0.15$, or 2.8 .
2. Anthrafilt, a product made from freshly mined anthracite coal, is an aeceptable substitute.

note:
To aperate filter, apen valves 1 and 2 . To backwash, close valve 1 ; after water olready in filter flows down to top af wash.water traugh, clase valve 2 and open volver 3 and 4. Ta run water from filter ta woste, clase valves 2,3 and 4 apen valves 1 and 5 .

Figure 41. Operating a gravity-type rapid sand filter.
3. Filter gravel, composed of hard, durable pebbles, is usually placed in graded layers, coarsest at the bottom, as follows:

| Layer No. | Passing screen opening (anches) | Retained on screen <br> opening (inches) | Depth of layer (inches) |
| :---: | :---: | :---: | :---: |
| 1. | 21自 | 11\%2 | 4 |
| 2 | -11/2 | $3 / 4$ | 6 |
| 3 | $3 / 4$ | 1/2 | 4 |
| 4 | 1/2 | 14 | 4 |
| 5 | 1/4 | 1/8 | 4 |

(c) Typical operating criteria.

1. Washing is needed when the loss-of-head gage, figure 42, shows a loss of 7 to 9 feet or after a filter run of 100 hours. (Sudden decrease in loss-of-head usually means cracks in the filter bed surface. These require prompt correction or a backwash, to insure satisfactory filtering.)
2. Best wash-water velocity is between 15 and 20 gpm per square foot of filter surface. This is equivalent to $\AA$ rise in water level of between 2 fect and 2.5 fect 4 inches per minute, with valve 4 (figure 41) in operating position. Normally the desirable velocity is the highest velocity which is attainable without loss of filter sand.
(7) Hypochlorinators.
(a) The standard portable pumping and hypochlorinator unit, 50 gpm , pumps water from a source, applics a hypochlorite solution, and delivers 50 gpm of chlorinated water against a head of 50 feet, of which 15 fect may be suction. It is useful for small installations.
(b) The standard portable automatic hypochlorinator, 2 to 100 gpm, when installed on a bypass connection assembly on a 4 -, 6 -, or 8 -inch main, chlorinates flows ranging from 2 to 400 gpm .


Figure 42. Loss-of-head measurement.


Figure 48. Improvised constant-flow chlorinating apparatus.
(c) Commercial type chlorinators may be available in existing installations. These usually require the use of liquid chlorine in cylinders.
(d) If neither standard nor commercial chlorinators are available, constant-flow apparatus is improvised as shown in figure 43 , and controlled manually.

## 89. Expedient Distillation

$a$. When necessary, expedient stills are built to produce potable water from a source of heat, a method of forming and collecting steam, and some kind of condenser. The efficiency of an expedient still
depends on the matcrials available and the ingenuity of the designer. In expedient distillation, sufficient vapor-scparating space is provided to prevent carryover of salt with the steam. Care is taken to avoid getting salt in the distillate through the expedient means used to condense the steam. To avoid endangering personnel by the building up of excessive stcam pressure, never put a valve in the distillate line.
b. Figure 44 illustratcs an expedient still with water-cooled condenser.


Figure 44. Expedient still, water-cooled condenser.

## 90. Hypochlorination Units

See table 80.

## 91. Water Demands

a. General. Delivery of water through a distribution system is continuous and in sufficient quantity to meet the maximum rate of demand (peak dcmand).
b. Peak Demand for a System. The size of a water main serving an area depends on the total pcak demand for that area. Servicc connections and mains are made large enough to deliver the total peak demand under the available pressurc. Figures 45 and 46 give the peak demand, in gallons per minute, in terms of the number of fixture units on a main. Figure 45 (1) is for a system with 240 fixture units or less; figure 45 (2), for a system with more than 240.
c. Fire-Protection Demand. In temporary installations it may be impracticable to construct distribution systems large enough to meet the dcmand of firefighting equipment. In such cases it is best to provide ground storage tanks or sumps, so loeated that any building ean be reaehed with not over 1,000 feet of hose. Watcr is pumped by fire pumper trucks or skid-mounted pumps.

Table 80. Hypochlorination Units

| Unit | Operation | Capabilitics | Length, Width, Height, Weight | Remarks |
| :---: | :---: | :---: | :---: | :---: |
| Hypochlorination unit, antomatic, portable. | Water-pressure operated. <br> Virtually automatic, requiring only 1 operator under all conditions. | Installed in $2^{\prime \prime}$ pipe or hose, it chlorinates water pumped at rates from 2 to 100 gpm . Installed on a bypass from 4- or 6inch main, it ehlorinates flows from 2 to 400 gpm . When set for maximum flows expected, the unit proportions the solution for flows down to one-tenth the maximum. | $\begin{aligned} \mathrm{L} & =25^{\prime \prime} \\ \mathrm{W} & =181^{\prime \prime} 2^{\prime \prime} \\ \mathrm{H} & =26^{\prime \prime} \\ \mathrm{Wt} & =165 \# \end{aligned}$ | For planning purposes, the chemi cal requirement is 1 ounce o calcium hypochlorite ( $70 \%$ avail able chlorine) per 1000 gallons See TM 5-2032 for details of operation. Requires a minimum continuous water pressure of 10 $\mathrm{psi} ; 5 \mathrm{psi}$ of which is lost to fric tion. There is a constant smal wastage of water from the unit. |
| Pumping and hypochlorination unit, portable. | Gasolinc engine coupled to a centrifugal pump with a belt-driven hypochlorinator. | This unit pumps and treats water which requires chlorination only. It delivers 55 gpm of chorinated water against a total head of 50 feet, 15 feet of which may be suction. | $\begin{aligned} \mathrm{L} & =31^{\prime \prime} \\ \mathrm{W} & =25^{\prime \prime} \\ \mathrm{H} & =38^{\prime \prime} \\ \mathrm{Wt} & =285 \# \end{aligned}$ | See TM 5-295 for details of operation. |



CURVE NO. 1 FOR SYSTEM W1TH FLUSH VALVES CURVE NO. 2 FOR SYSTEM WITH FLUSH TANKS

Figure 45 (1). Supply-demand curve, for fixtures not exceeding 240.

## 92. Water Pressures

a. Supply Mains and Pumps. Working pressures for the supply mains vary with the cquipment a vailable. The pumps and equipment described in TM $5-350$ are designed for maximum pumping pressures of 200 to 400 pounds to the square inch. High pump pressure permits the usc of smallcr pipe without reducing the supply-main capacity. However, prcssure must be multiplied by about 4 to double the capacity of a main, whereas doubling the cross-sectional area of the main accomplishcs about the same result. It is materially more economical to operatc and maintain pumps and pipes at 100 to 150 pounds to the square inch than at higher pressures.
b. Distribution. Pressures in distribution mains are held down-by pressure-reducing valves, if neccssary-to avoid exceeding the allowable pressure at outlets. This allowable pressure is established to minimize faucet leakage, wear and tear on faucets and fixtures, and water-hammer damage. It is usually set at between 20 and 75 pounds to the square inch and as near 20 pounds to the square inch as will


Figure 45 (2). Supply-demand curve, for fixtures in excess of 240 units.
prevent outlet pressures from falling below 20 pounds to the square inch at a time of peak demand. A valved bypass around the reducing valve permits any temporary pressure increase needed for firefighting.
c. Characteristics of Pipes. Table 81 gives dimensions, weights, and other data of standard steel and other pipes in ordinary use. See also table 155. For friction losses, see paragraph 93. For comparative discharge capacities, see paragraph 95 .

## 93. Friction Losses

Friction losses in service connections and distribution mains are normally based on the use of iron or steel pipe, using the $\mathrm{C}=120$ in the Hazen and Williams formula for temporary camps, and $\mathrm{C}=100$ for permanent camps. The alinement charts in figures 46 and 47 are used for computing friction losses in straight pipes and in valves and fittings.

Table 81. Properties of Pipeline Materials

| Itcm | Normal sizes |  | Physical properties |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Length (ft.) | Diameter (in.) | Frietion ${ }^{1}$ coefl. C | Working press (psi) | Weight per lin. ft. (lb.) |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  | $3 / 4$ | 2 | 4 | 6 | 8 | 12 | 18 | 24 | 36 | 48 |
|  | 12------------. | 4 to 84....-....- | 140 (new) to 100 | Class A, 50..-- |  |  | 192 | 30.0 | 42.9 | 73.3 |  |  |  |  |
|  |  |  | (old). | Class B, 100... |  |  | 19.2 | 30.0 | 42.9 | 73.3 |  |  |  |  |
|  |  |  |  | Class C, 150... |  |  | 19.2 | 30.0 | 42.9 | 77.9 |  |  |  |  |
|  |  |  |  | Class D, $200 \ldots$ |  |  | 19.2 | 30.0 | 42.9 | 838 |  |  |  |  |
| Stecl, API.-----.---------------------- | 20---------.---- | 4,6,8......--- | 140 | 1,400 (4') .---- |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | 1,300 ( $6^{\prime \prime}$ ) $\ldots \ldots$. |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | 950 ( $8^{\prime \prime}$ ) .-....- |  |  |  |  |  |  |  |  |  |  |
| Steel, pipclinc tubing.------------------ | 20-------------- | 4, 6......------- | 140... | 650...---------- | --- | ------ | 4.8 | 10.9 | 16.2 | ------ | ---- | ----- |  | ------ |
| Steel, stamless or wold.-........----..... |  | 34, 112, 2-.... | 140 | Std.---------- | 1. 1 | 3.7 | 10.8 | 19.2 | 28.8 | 50.7 |  |  |  |  |
|  |  | 4, 6, 8-. |  | Extrastrong. .- | 1.5 | 5.0 | 150 | 28.6 | 43.4 | 65.4 |  |  |  |  |
| Wrought iron--------------------------- | 20-.------------ | $3 / 4,2,4,6,8 \ldots$ | 130 to 140. | Std. | 1.1 | 3.7 | 10.9 | 19.2 | 28.8 | 50.7 |  |  |  |  |
|  |  |  |  | Extrastrong.-. | 15 | 5.0 | 15.0 | 28.6 | 43.4 | 65.4 | -- |  |  | ------ |
|  | 6-16...------.-. | 4, 6, 8, 12 $\ldots \ldots$ | 120--- | 45--.---------- | ----- | --..- | 5.8 | 8.7 | 11.2 | 17.7 | 28.8 | 41.4 | --..-- | ------ |
| Bituminized fibcr.-..------.......... | $8\left(4^{\prime \prime}\right), 5\left(6^{\prime \prime}, 8^{\prime \prime}\right)$ | 4, 6, 8-------- | 150-------------- |  | ----- |  | --- | -.... | ----- | ---- |  | -- | ----- | ------ |
| Asbestos cement (transite).....-...--.-- |  | 2 to 31/2-- | 140 | 50 |  |  | 4.7 | 7.6 | 11.7 | 19.8 | 35.9 | 55.5 | 126 |  |
|  | 13.------------- | 4, 6, 10, 12....- |  | 100 |  |  | 5.0 | 7.8 | 11.9 | 27.6 | 58.2 | 99.3 | 211 | ------ |
|  |  | 14, 16, 18, 20..- |  | 150. |  |  | 6.0 | 107 | 16.8 | 38.6 | 81.2 | 141 | 318 | ------ |
|  |  | 24, 30, 36. $\ldots$.-- |  | 200. |  |  | 8.4 | 15.4 | 23.7 | 49.6 | 112 | 199 | 435 | ------ |
|  | 2, 25, 3, 4-....-- | 4 to 24 | 130 to 140. |  | ----- | -----. | ----- | 25 | 35 | 160 | 120 | 225 |  |  |
| Conerete sewer, reinlorced..-..------.- | 1.-------------- | 12 to 100.----- | 130 to 140 | -------------- | ------ | ------ | ------ | ----- | ----- | 100 | 160 | 260 | 450 | 720 |
| Concrete culvert, reinforced...-------.- | 3----------..--- | 12 to 100..----- | 130 tol40------- | ------------- | ----- | ----- | ----- | ----- | --- | 100 | 160 | 320 | 520 | 850 |
| Concrete culvert, extrastrong ----------- | 3-------------- | 24 to 100-.--... | 130 to 140..-. -... | ------------ | ----- |  | ----- | ----- |  | - |  | 320 | 520 | 850 |
|  | 2, 2.5, 3...-.-.--- | 4 to 36-.------- | 110-... |  | ---.-. | ---.. | 8.0 | 145 | 23.0 | 43.5 | 96.0 | 172 | 370 | ------ |
| Clay, culvert-.----------------------- | 2, 3-------------- | 6 to 36.-------- |  |  | ----- | -.... | -- | 15.5 | 24.0 | 55.5 | 116 | 218 | 505 | ----- |
| Corr. metal: |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 16 ga .. | 2.----------.--- | 8 to 84.-------- | Less than 100..-- |  |  |  |  |  | 7.6 | 10.8 | 15.8 | 21.0 | -.. |  |
| 14 ga |  |  |  |  |  |  |  |  | 0.3 | 13.3 | 195 | 26.0 | 37.9 | 50.5 |
| 12 ga | ---------------- |  | .----------.... |  |  |  |  |  | ---- | 18.5 | 27.0 | 35.9 | 52.4 | 70.0 |

Table 81. Properties of Pipeline Materials-Continued

${ }^{1}$ Hazen Williams.
Note. Weights of concrete and corrugated metai pipe in $15^{\prime \prime}, 21^{\prime \prime}, 30^{\prime \prime}$, and $42^{\prime \prime}$ sizes may be interpolated from data shown. Weights or strengths of asbestos-cement pipe In $10^{\prime \prime}, 14^{\prime \prime}, 10^{\prime \prime}, 20^{\prime \prime}$, and $30^{\prime \prime}$ sizes also may be estimated by interpolation.


NOMOGRAM FOR CALCULATING PIPE SIZE, DISCHARGE AND HEAD LOSS
The above nomagram is based on the Willams-Hazen formulo: $\mathbf{Q}=.006756 \mathrm{CD}^{20}{ }^{0}{ }^{34}$. The coefficiont of cement-lined Mono-Cost pipe is 140.

Figure 46. Alinement Charl for calculating pipe size, discharge, and head loss.

EXAMPLE: DOTTED LINE SHOWS THAT RESISTANCE OF A 6" STANDARD SHORT RADIUS ELBOW IS EOUIVALENT TO 16' OF 6" STANDARD PIPE.


Figure 47. Friction chart for valves and filtings.

Table 82. Schedule of Fixtures per Branch

| Size of branch (inches) | Connections allowed |  |
| :---: | :---: | :---: |
|  | . Size (inches) | Number |
| 3/8- | 3/8 | 1 |
| $1 / 2$ | 3/8 | 5 |
| 1/2- | 1/2 | 3 |
| 3/4- | $1 / 2$ | 8 |
| 1 | 1/2 | 15 |
| 11/4 | 1/2 | 27 |
| 11/2- | 1/2 | 42 |

Table 83. Recommended Pipe Sizes for Fixture Branches

| Fixture | Fisture branch size (inches) |
| :---: | :---: |
| Lavatory | $3 / 8$ for hot and cold. |
| Bathtub. | 1/2 for hot and cold. |
| Kitchen sink, small. | $1 / 2$ for hot and cold. |
| Kitchen sink, large scullery | $3 / 4$ for hot and cold. |
| Laundry trays. | $1 / 2$ for hot and cold. |
| Shower stall per head. | $1 / 2$ for hot and cold. |
| Water closets, flush-tank | 3/8 cold. |
| Water closets, flush-valve | 1 cold. |
| Pedestal urinals, flush-valve | 1 cold. |
| Wall type urinals, flush-valve | 1/2 cold. |

Table 84. Rates of Flow Through Fixtures :

| Fixture | Gallons per minute |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Number of Fixtures | 1 | 2 | 3 | 4 | 6 | 8 | 10 | 15 | 20 | 25 |
| Water closcts with tanks | 5 | 10 | 12 | 15 | 23 | 26 | 40 | 50 | 66 | 75 |
| Urinals with tanks | 4 | 8 | 10 | 12 | 20 | 23 | 34 | 48 | 58 | 65 |
| Water closets, flush-val | 27 | 45 | 55 | 70 | 95 | 115 | 135 | 150 | 170 | 200 |
| Urinals, flush-valve | 15 | 25 | 33 | 45 | 58 | 75 | 82 | 88 | 94 | 100 |
| Lavatories (bascd on 1 faucet) | 3 | 5 | 8 | 10 | 15 | 18 | 24 | 33 | 40 | 48 |
| Bathtub (based on 1 fauect) | 10 | 18 | 26 | 32 | 45 | 56 | 66 | 90 | 120 | 150 |
| Shower hcad, watersave |  | 8 | 12 | 16 | 20 | 24 | 30 | 45 | 55 | 70 |
| Shower head, rain type | 8 | 16 | 24 | 32 | 42 | 56 | 70 | 95 | 120 | 150 |
| Kitchen sink, small (per faucct) | 6 | 10 | 14 | 16 | 24 | 32 | 40 | 54 | 70 | 85 |
| Kitchen sink, large (per faucet) | 8 | 14 | 18 | 24 | 32 | 40 | 50 | 63 | 91 | 103 |
| Scrvice sink (per faucct) | 10 | 18 | 24 | 28 | 36 | 44 | 52 | 68 | 88 | 110 |
| Laundry tray (per faucct) | 8 | 14 | 18 | 24 | 32 | 40 | 50 | 63 | 81 | 103 |
| Drinking fountains | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 15 |
| Hose bibbs, $1 / 1 /$ inch | 5 | 8 | 11 | 14 | 25 | 34 | 40 | 60 | 80 | 100 |

[^22]
## 95. Comparative Discharge Capacities of Water Pipes

Table 85. Comparative Discharge Capacities of Water Pipes

| Size of pipe (inehes) | Number of equivalent pipes |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 38 | 1/2 | 34 | 1 | 13/4 | 1 $1 / 2$ | 2 | 236 | 3 |
| 3/8 | 1 |  |  |  |  |  |  |  |  |
| 1/2 | 1. 8 | 1 |  |  |  |  |  |  |  |
| 3/4 | 3. 6 | 2 | 1 |  |  |  |  |  |  |
| 1. | 6. 6 | 3. 7 | 1. 8 | 1 |  |  |  |  |  |
| 11/4 | 13 | 7 | 3. 6 | 2 | 1 |  |  |  |  |
| 1122 | 19 | 11 | 5. 3 | 2. 9 | 1. 5 |  |  |  |  |
| 2 | 36 | 20 | 10 | 5. 5 | 2. 7 | 1. 9 | 1 |  |  |
| 21/2 | 56 | 31 | 16 | 8 | 4. 3 | 2. 9 | 2 |  |  |
| 3 - | 97 | 54 | 27 | 15 | 7 | 5 | 2. 8 | 1. 8 |  |

Note. To find number of smaller pipes equal to a larger size, read down from smaller pipe size, across from larger size; read answer at intersection. Tbus, capacity of one 212 -inch pipe equals capacity of eight. 1 -inch plpes.

## Section II. SEWERAGE

## 96. General

The subject of sewerage is dealt with in a general way in TM 5-302 and TM 5-283. Further details are given in TM 5-665 and TM 5-666. Sanitary aspects of the problem are discussed in FM 21-10.

## 97. Quantities of Sewage

The quantity of sewage that is disposed of varies with the number of personnel served and the restrictions placed on the use of water. Flows generally range between 15 and 50 gallons per capita per day, although permanent installations with ample water supplies may use more. The average flow from temporary installations is about 25 gallons per capita per day, and this is increased by 50 gallons for each bed in hospitals. The peak rate of flow for short periods in the day may be three times the average rate. The curve in figure 48 shows the ratio of peak flow to average flow.

## 98. Stream Flow Required For Dilution

The amount of stream flow required for disposal by dilution depends on the strength and quantity of the sewage, the density and nearness of the population to the stream bank, and the industrial or domestic use of the stream water below the outfall. A stream overloaded with sewage develops sludge banks and surface scum, is unsightly, and emits an offensive odor. For streams not used for industrial and domestic water supply below the sewage outfall, table 86 provides a guide in determining the quantity of sewage that may be discharged. This table gives the minimum stream flow required for dilution of raw and treated sewage. If enough water is not


Figure 48. Ratio of peak to average sewage flow.
available for dilution, oxidation ponds, leaching cesspools, or tile distribution fields are used for disposal of surplus sewage, taking adequate precautions to avoid contamination of the water supply.

Table 86. Minimum Stream Flow Required for Dilution

| Type of treatment | Dilution per 1,000 sewage-contributing population |  |
| :---: | :---: | :---: |
|  | Densely populated areas | Sparsely populated areas |
| None. | 20 c.f.s. and over_ | 5 c.f.s. and over. |
| Partial (settling) | 12 to 20 c.f.s | 3 to 5 c.f.s. |
| Complete.- | 6 to 12 c.f.s | 0 to 3 c.f.s. |

## 99. Sanitary Sewers

a. Layout. To avoid deep excavations sewers are located along natural drainage lines. If possible, they are not laid longitudinally under roadways. Road crossings are kept to a minimum and where less than 4 feet of cover is available the pipe is reinforced by backfilling the lower 2 feet of the trench with low-grade concrete. In light traffic areas, sewers should be covered with at least 2 feet of well-compacted earth. Connections adjoining buildings may need only 1 foot of cover. Manholes are located at each change of direction, size, or slope and usually are placed at the end of each lateral. On


Figure 49 (1). Pipe flow diagram.


Figure 49 (2). Proportionate flow chart.
straight sections of sewers, the maximum distance between manholes is 400 feet. Two hundred to three hundred feet spacing is preferable.
b. Size. The size of sewer required to carry a given capacity depends on the slope of the sewer and the resistance to flow caused by the interior surface of the pipe. Pipes less than 4 inches in diameter (on a slope of $3 / 16$-inch per foot) are not used, because they clog and require frequent cleaning. Four-inch pipe may be used on house sewers; lateral sewers are 6 inches or more in diameter.
c. Velocity. To prevent the settling out of solids the minimum velocity is 2 feet per second when the sewage flow is at the full capacity of the sewer. However, in unfavorable terrain a velocity of 1.5 fps is satisfactory.

## 100. Sizes of Sewer Lines

a. Table 87 is based on an assumed peak load of 75 gallons per capita per day. (This is for permanent installations; in a theater of operations, use 25 gallons per day.) Flow is from Kutter's formula, using $\mathrm{n}=0.013$. For further information see pipe flow diagram (figure 49 (1)) and proportionate flow chart (fig. 49 (2)).
$b$. The following examples illustrate the use of the pipe flow diagram and the proportionate flow chart as shown in figures 49 (1) and 49 (2).
(1) To determine pipe size:

Assume a peak sewage flow of 150 GPM on a $1 \%$ slope. Using Figure 49 (1) find intersection of horizontal line from 150 GPM and vertical line of $1 \%$. This falls below a $6^{\prime \prime}$ Pipe-the $6^{\prime \prime}$ must be used on a trial basis. Then using a $6^{\prime \prime}$ pipe on a $1 \%$ slope the flow conditions for FULL FLOW can be found; i.e., 230 GPM capacity and 2.5 fps velocity. To find what the actual flow conditions would be, Figure 49 (2) must be used.
(2) To use Proportionate flow chart 49 (2) the Proportionate discharge must be found by :

$$
\frac{\mathrm{QACTUAL}}{\text { QFULL FLOW }}=\frac{\mathrm{QA}}{\mathrm{Q}_{\mathbf{c}}}=\frac{150}{230}=0.65
$$

By entering proportionate flow chart at 0.65 construct perpendicular line to discharge curve then horizontal to velocity thence straight down and read proportional velocity $\frac{\mathrm{V}_{\mathrm{A}}}{\mathrm{V}_{c}}$ is 1.06 -the actual velocity at 150 GPM will be $1.06 \times$ 2.5 or 2.7 fps .

Table 57. Sizes of Sewer Lines

| Pipe diameter (inches) | 2-f.p.s. velocity |  |  | 1.5-f.p.s. velocity |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Slope (ft. per 100 ft.) | Discharge (g.p.m.) | Population capacity | Slope (ft. per 100 ft .) | Discharge (g.p.m.) | Population capacity |
|  | 0. 63 | 176 | 3, 300 | 0. 36 | 132 | 2, 500 |
| 8. | . 40 | 314 | 6,000 | . 23 | 235 | 4,500 |
| 10 | . 28 | 490 | 9, 000 | . 16 | 368 | 7,000 |
| 12. | . 21 | 707 | 13, 000 | . 12 | 530 | 10,000 |
| $14{ }^{1}$ | . 17 | 960 | 18, 000 | . 095 | 721 | 13, 000 |
| 15 | . 15 | 1,104 | 21,000 | . 086 | 828 | 15, 000 |
| $16^{1}$ | . 14 | 1,260 | 24, 000 | . 078 | 942 | 18, 000 |
| 18 | . 12 | 1, 590 | 30, 000 | . 067 | 1, 192 | 22, 000 |
| $20^{1}$ | . 10 | 1, 970 | 37, 000 | . 056 | 1, 472 | 28,000 |
| 21 | . 09 | 2, 160 | 41, 000 | . 053 | 1, 623 | 31, 000 |
| 24 | . 076 | 2, 825 | 54, 000 | . 044 | 2, 120 | 40, 000 |

${ }^{1}$ These sizes are nonstandard sewer sizes.

## 101. Treatment of Sewage

a. Type. If treatment is required, the type of treatment and plant depend on the quantity and type of sewage, soil conditions, receiving waters, materials and labor available, and the climate. The Army Medical Service is responsible for determining the degree of treatment
required before disposal. Partial or eomplete treatment depends on the conditions controlling the disposal methods.
b. Site and Layout. The main consideration in selecting the treat-ment-plant site is the location of the final receiving ground or diluting water. The treatment plant should be downwind and far enough away from populated areas to avoid odor nuisance. Other factors influencing site selection are the elevation above floodwater level and the ground slope for gravity operation. Unless there is a 10 - to 15 -foot drop to provide gravity flow through complete treatment plants, the sewage is pumped. All treatment plants have a bypass for use during repair and maintenance. Plants which serve more than 5,000 persons are built generally with multiple tanks, filters, and other facilities, and the pipes are arranged so that parts of the plant can be bypassed for cleaning and repairing without putting the entire installation out of operation.
c. Capacity. Designs of tanks, basins, and other units within a treatment plant are based on the average anticipated flow for the required retention period. All pipes and channels within the plant are designed to carry the peak flow at velocities of not less than 2 feet per second.
d. Design. Standard designs for small sewage-treatment plants are shown in TM $5-302$. When primary sedimentation and sludge digestion are sufficient to meet the needs for treatment of the sewage, only the Imhoff tank and sludge-drying beds are constructed, but if complete treatment is required, the trickling filter and final settling tank are also provided. This design criterion should be followed if larger plants are required. Important factors are the contributing population, settling time, filter loading, sludge-digestion capacity, and sludge-drying-bed area. The area required for sludge-drying beds with drains is $1 \frac{1}{2}$ sq. ft. per eapita; without drains it is $4 \frac{1}{2}$ sq. ft . per capita.

## 102. Septic Tanks

Septic tanks may be used for small installations in isolated places where the soil is suitable for underground disposal, and where conneetion to a sewer system or discharge into a watercourse is not practicable. TM 5-302 shows a design of a septic tank, tile field, and leaching well, and design criteria for these facilities.

## 103. Surface Irigation

a. Rate of Application. Disposal rates (rate of application) of sewage by surface irrigation vary with the permeability of the soil, ranging as high as 60,000 gallons per acre per day. To estimate the rate of application, dig a hole 1 foot square and 1 foot deep and fill it with water. When the water has seeped away but the bottom of the hole is still wet, pour 6 inches of water in the hole and note the time
required for the water level to drop 1 inch. This time in minutes corresponds to the permissible rates of sewage application shown in table 88, which are furnished only as a guide.
b. Ground Recovery. Ground used for surface irrigation must be rested. With use, the surface will clog•and must be scraped off. Allowances for ground resting and recovery, field maintenance, and normal rainfall are included in the above table.

Table 88. Surface Irrigation; Gallons per Acre per Day

| Time for water to fall 1 inch in test hole (minutes) | Average rate of application (gallons per aere per day) |
| :---: | :---: |
| 1. | 57, 700 |
| 2 | 46, 800 |
| 5 | 34, 800 |
| 10. | 25, 000 |
| 30. | 12, 000 |
| 60. | 8, 700 |

## 104. Leaching Cesspools

Leaching cesspools are closed or covered pits, usually with masonry walls and an unlined bottom, through which liquids percolate in to the surrounding soil. Solids settle to the bottom of the pit where they are digested. Occasionally, it may be neccssary to pump or bail the sludge. Leaching cesspools range from 4 to 6 fect in diameter and from 6 to 20 feet deep. The depth of leaching cesspools is governed by the depth of permeable soil and the ground-water level. Masonrylined walls are laid dry with open joints to within 4 feet of the surface. If more than one cesspool is required, they are connected in series and are located at least 20 feet apart. Size can be determined by filling a 1 -foot-square hole with 6 inches of water, and allowing it to seep away. While the bottom of the hole is still wet, fill again to a depth of 6 inches and observe the time in minutes for the water in the test hole to fall 1 inch. The time in minutes is applied to the permissible rates shown in table 89, which are furnished only as a guide.

Table 89. Leaching Cesspools; Square Feet/Gallons Per Day

| Time for water in test hole to fall 1 inch (minutes) | Required surface area of bot tom and side walls in confeet per 100 gallons per day) |
| :---: | :---: |
| 1. | 19 |
| 2 | 23 |
| 5 | 31 |
| 10 | 44 |
| 30 | 91 |
| 60 | 111 |

## 105. Subsurface Irrigation

Settled sewage is disposed of by subsurface irrigation, a method commonly used in eonjunetion with cesspools or septie tanks at small installations. The main distributors are laid with tight, but not nucessarily waterproof, joints. The tile pipe of the laterals, usually 4 to 6 inehes in diameter, is laid end to end with a $1 / 4$-inch spaee between lengths. The top two-thirds of the joint is eovered with roofing paper to keep the soil from washing into the line. Perforated bitumenized fiber pipe, if available, is laid with tight end joints and perforations downward. Laterals are laid in a gravel-filled shallow treneh with about a 6 -ineh fall per hundred feet for unregulated flow and about a 4 -inch fall per hundred feet where a dosing system is used. Laterals are spaced 5 to 10 feet apart and are gencrally 75 to 100 feet long. To determine the length of the tile drain system, dig a 1 -footsquare test hole to the depth of the proposed tile drains. Fill the hole with water to a depth of 6 inehes and observe the seepage. While the bottom of the hole is still wet, fill again to a depth of 6 inches and observe the time in minutes for the water in the test hole to fall 1 ineh. The time in minutes is applied to the permissible rates shown in table 90 , which are furnished only as a guide.

Table 90. Subsurface Irrigation; Gallons Per Day Per Hundred Feet of 18-Inch Trench

| Time for water to fall 1 inch in test hole (minutes) | Average rate of application (g.p.d. per 100 feet of trench 18 inches wide) |
| :---: | :---: |
| 1. | 600 |
| 2 | 480 |
| 5. | 360 |
| 10 | 255 |
| 30 | 120 |
| 60 | 90 |

## 106. Chlorination

Where the eondition exists that through failure of power or equipment there is a possibility of eontaminating a water supply with raw sewage, provisions are provided for chlorinating at a rate of 200 pounds per million gallons at the 4 -hour rate of sewage flow. In other eases where chlorination is required, provisions are made for chlorination at a rate of 125 pounds per million gallons at the 4 -hour peak rate of flow. The 4 -hour peak rate is considered to be 175 pereent of the average daily rate of flow. Chlorine is sometimes used to delay the oxygen demand until the sewage raehes a body of water large enough to provide the oxygen required. It is also effective in killing pathogenes if the contact period and the
-chlorinc concentration are sufficient, and all particles are finely enough divided to permit chlorine contact. The chlorine dosages given in table 91 are high and are designed to safeguard health and prevent scrious nuisance in emergencies; they are substitutes for other processes of sewage treatment. Chlorine is applied by mechanical chlorinators or an improvised drum chlorinator. The data given in table 91 are based upon obtaining a chlorine residual of 0.5 parts per million after a contact time of 15 minutes.

Table 91. Sewage Chlorination Dosages

| Type of sewage or effluent | A proximate dosage (pounds per day hquid chlorine per 1.000 persons) |
| :---: | :---: |
| Raw sewage | 40 |
| Settled sewage_ | 30 |
| Trickling-filter effluent. | 10 |
| Surface- or subsurface-irrigation effluent | 5 |

## 107. Maintenance of Sewers

a. Repair. Sewer repair consists principally of replacing broken manhole covers and ring assemblies and cracked or crushed lengths of pipe. Sections of bell-and-spigot clay pipe are installed by chipping off one-half the bell of the length to be inserted, chipping off upper portion of bell on the section of pipe below the gap, inserting the new section and rotating so the unchipped half of the bell is on the bottom, and completing the joint with mortar or mastic.
b. Methods.
(1) Stoppages. The clearing of stoppages is the most important item of sewer maintenance. Tree roots, particularly poplars, willows, and elms, penetrate pipe joints and clog sewers. Large objects and deposits decrease or stop flow. Sluggish flow, accumulated scum, or sewage backed up in a manhole indicates that repair or cleaning is requircd.

## (2) Methods.

(a) Sewers are cleaned by push rods, wooden balls, or flushing. Push rods 4 feet long are jointed and pushed through the sewicr from manbole to manhole. Special tools are attached to the first rod to clear dcposits or cut tree roots. The use of rods becomes difficult when the distance excecds 300 feet.
(b) Wooden balls of one-half or three-fourths the diamcter of the pipe can be used to clean deposits from sewers. They are placed in the sewcr and recovered by placing a coarse screen in the manhole downstrcam. The sewage
backed up behind the ball escapes around it at high velocity, scouring out solids deposited in the pipe.
(c) Sewers are flushed out by damming the outlet in a manhole with a sandbag, and removing the bag with an attached rope after the manhole has partially filled. Backed-up sewage is then released to scour out deposits. Care is taken not to back up sewage into fixtures and inlets in buildings. Discarded fire hose also is used for flushing. Water pressure makes the hose stiff enough to be pushed through short lengths of pipe.
c. Safety. Sewer gas, methane, hydrogen sulfide, or gasoline and oil drainings can fill sewers with explosive mixtures. Carbon monoxide is particularly dangerous because it is often present in sewers and is not perceptible to the human senses. It may cause a slight headache preceding unconsciousness. Although some of the lighter gases are removed by opening manholes, the weight of carbon monoxide is about the same as air and it is removed only by using a blower. Sewer repair men should work in pairs, one staying above ground to observe and aid the other if necessary. A rope is sometimes tied around the man below ground to lift him out if he becomes unconscious. Chemical detectors for carbon monoxide are made, but if they are not available, a bird in a cage lowered into a manhole is observed for the effects of gas. A considerable concentration of carbon monoxide makes a man unconscious almost immediately, and death is avoided only by artificial respiration, immediately and properly administered.

## Section III. REFUSE COLLECTION AND DISPOSAL

## 108. General

$a$. Refuse consists of garbage, rubbish, ashes, debris, and other domestic and commercial solid waste material.
(1) Garbage is the animal vegetable waste and containers resulting from the handling, preparation, cooking, and consumption of foods.
(2) Rubbish consists of discarded unsalvaged waste material such as metal, glass, crockery, floor sweepings, paper, wrappings, containers, cartons, and similar articles.
(3) Ashes include the residue from burning wood, coal, coke, and other combustible material used in heating and cooking.
(4) Debris consists of such items as grass cuttings, tree trimmings, stumps, street sweepings, roofing and construction wastes, and similar waste material resulting from construction, maintenance, and repair work.
b. Refuse collection and disposal are discussed in TM 5-634.

## 109. Methods of Disposal

Refuse is disposed of by burying in a sanitary fill, by incincration, by dumping at sea, or by contract with disposal services.

## 110. Collection

A regular schedule and system of collection is established to fit the particular disposal method. In all cases, stands are installed for cans used for storage of garbage. Military organizations must provide facilities at each messhall for the sanitary handling and storage of garbage until it is collected and for the proper cleansing of cans which are not removed by collectors (TM 5-634). The list of average weights of materials given in table 92 is a guide to handling collections.

Table 92. Average Weights of Garbage and Refuse Materials

| Material | Weights (pounds) |  |
| :---: | :---: | :---: |
|  | Per 32-gallon can | Per cubic foot |
| Garbage | 150 to 225 | 35 to 53. |
| Refuse without garbage or ashes_ | 28 to 36 | 6.5 to 8.5. |
| Refuse including garbage | 39 to 47 | 9 to 11. |
| Refuse including both garbage and ashes . - | 56 to 64 | 13 to 15. |
| Ashes | 141 to 158 | 33 to 37. |

## 111. Disposal by Sanitary Fill

A sanitary fill is an effective method of permanently disposing of all types of waste including dry trash, incombustible rubbish, edible and nonedible garbage, in nearly any proportion. Waste materials are placed in a continuous series of sealed cells, compacted, and thoroughly scaled under 2 feet of dirt. The earth covering is obtaincd from succceding trenches dug parallel to the original trench. The sanitary-fill method eliminates rat, fly, and mosquito hazards, and smoke and odors resulting from open fires and dumps. Burning materials in sanitary-fill trenches is not permitted because it greatly lessens the effectiveness of the installation and complicates operation. Complete details for the siting, construction, and operation of sanitary fills are given in TM 5-634. The depth of the original trench, and the depth of the compacted material, depend on the sizc of the installation using the fill and on the amount and kind of waste. Table 93 is a guide to be used in determining the depth of the original trench and the depth of the compacted material. Since the second and succeeding trenches are dug only to obtain enough dirt for a 2 -foot covering over the compacted refuse in the preceding trench, they necd not be ovcr 3 feet deep.

Table 99. Depths, Sanitary Fills

| Size of installation | Depth of eompaeted refuse (feet) | Depth of original treneh (feet) |
| :---: | :---: | :---: |
| 1,000 to 2,000 men | 3 | 2122 |
| 2,000 to 4,000 men | 312 | 3 |
| 4,000 to 6,000 men | 4 | $31 / 2$ |
| 6,000 to 8,000 men | 5 | 4 |
| 8,000 to 10,000 men | 6 | 4 |

## 112. Disposal by Incineration

a. General. Incineration is the disposal of refuse by burning in specially constructed furnaces. Incineration destroys all organic matter, both gaseous and solid, and climinates all substances likely to undergo bactcrial decomposition. Garbage, rubbish, dead animals, and dried sludge from sewage disposal are burned in incincrators. Mixed refuse usually contains enough combustible matcrial to provide the fuel for burning. Additional fuel is uscd when burning garbage alonc.
b. Garbage is shoveled through a charging hole and onto an inclined drying hearth. Flames and hot gases produced by burning material on the grate dry the wet garbage on the drying hearth. As the garbage dries, it falls or is raked down to the burning grates where it burns and forms a solid mass or clinker. This clinker is broken up from time to timc and removed to keep it from clogging the burning grate. The ash falls into a pit under the burning grate and it is removed when necessary. The ash is disposed of in open dumps.
c. Construction. One large centrally located incinerator for a base camp or hospital is generally more efficient than a separate small incinerator for each unit. However, when the construction of one central incinerator is not possible, several smaller incinerators are built. Occasionally, because of the limited capacity of incinerators, it is necessary to construct a battery of incinerators at the central location. Construction details for incincrators are given in TM 5-280 and TM 5-634.
d. Operation. For adequate drying and combustion, the incinerator is heated before attempting to dispose of garbage. A fire is started in the furnace with clean, dry rubbish saved from a previous operation or with wood or coal. After the furnace is hot, the wet refuse is placed on the drying grate at reasonable intervals. Care is taken not to overload the incinerator with wet garbagc. As the garbage dries, it is noved toward the burning grate making room on the drying grate for the next charge of wet garbage. Garbage is stored as close to the charging holes as possible for ease in charging. To make the greatest usc of the heat, the plant should be operated with as few shutdowns as
possible. The charging boles are kept open only when absolutely neeessary, because the furnace cools rapidly. Tin cans carried into the furnace with the garbage are removed frequently to prevent decreasing the burning capacity of the grates. Glass, ehina, box straps, and other metal scrap are removed from the refuse before burning beeause they impair the efficiency of the incinerator.
$e$. Collection. Garbage is brought to the incinerators in cans or in truck bodies. The garbage is stockpiled at the eharging hole from the cans or trueks. The collection schedule is arranged so laek of garbage does not stop the incinerator. The best colleetion time is during the forenoon.

## 113. Disposal by Dumping at Sea

Disposal by dumping at sea is not recommended where other methods can-be used. It is most practieable for island installations, where the use of sanitary fills is impossible or the eonstruction of ineinerators is not feasible. Where islands are close to an inhabited friendly shore, or the body of water is relatively small, disposal by dumping at sea is inadvisable. When dumping in large bodies of water, the direction of prevailing winds and eurrents is considered so as to prevent return of the garbage to shore and to avoid defiling shores elsewhere. The garbage is loaded direetly from eans or trucks onto the barge, scow, or other means of transportation, hauled at least 5 miles offshore, and dumped.

## 114. Disposal of Refuse Alone

a. General. Garbage type ineinerators and sanitary fills are not practicable for disposing of large amounts of crating, scrap lumber, street sweepings, and incombustible trash. Crating and lumber produee too much heat for ordinary ineinerators. The two common methods of disposing of refuse alone are burning pits and regulated dumps.
b. Burning Pits. Masonry or earth pits of varying size and design to meet loeal requirements are used to burn eombustible refuse. However, they are fire hazards and their construetion and method of operation must be approved by all fire-protection agencies. The pits are cleaned weekly and all ashes, metal, and other ineombustibles are disposed of on regulated dumps. The design of earthen pits depends on the terrain and the quantity of refuse to be burned. A suggested design is a revetment with two horseshoe-shaped cells; each eell is used alternately for dumping and burning. If the pit is large, the ashes are left in the bottom, but periodieally they are leveled with a bulldozer or scraper. If the area of the pit is limited, the ashes and incombustibles are removed and plaeed on a regulated dump.
c. Regulated Dumps. Regulated dumps are used to dispose of incombustible trash. They are built like embankments or highway fills of limited height and area and situated so that they are compacted daily by truck traffic. They are leveled periodically by a bulldozer and kept orderly and free of objectionable contents. If properly operated, regulated dumps are used to reclaim worthless land. Refuse is not dumped over an embankment or the brow of a hill making a high-face dump, because dumps of this kind are difficult to operate under regulated-dump standards.

## Section IV. ELECTRIC-POWER DISTRIBUTION

## 115. General

Electric transmission and distribution is discussed in detail in TM $5-765$. Power generation in the field is developed in TM 5-766.

## 116. Foreign Voltages and Frequencies

Electric current for lights, motors, and other appliances is usually used at voltages of 115 or 208 volts and distributed at multiples thereof, but there are important exceptions; e.g., the prevailing voltage in Japan is 100 . As to the frequencies in alternating current, the lower frequencies permit higher power factors in certain types of motors but cause flicker in incandescent light. The present standard frequency in the United States is 60 cycles, except that 25-cycle current is used for power in some industrial installations. In Europe, a frequency of 50 cycles for illumination and 25 - and 42 -cycle current for power are standard. Direct-current voltages and alternatingcurrent voltages and frequencies generally used in various countries are given in table 94 (low-voltage supplies only).

## 117. Single-Phase Systems

Buildings containing single-phase equipment, such as lights, X-ray machines, or single-phase motors are served by two- or three-wire systems. Small loads as required for barracks lighting are served by two-wire systems; large loads require three-wire service.
a. Two-Wire Systems. In single-phase systems using two wires, the current in one wire always equals the current in the other, but flows in the opposite direction. Currents in the two wires reverse simultaneously.
b. Three-Wire Systems. Single-phase systems of three wires supply two voltages simultaneously. One wire is the neutral and is grounded; the other two are the hot wires. Figure 50 shows a typical singlephase three-wire system.

Table 94. Worldwide Direct-Current and Alternating-Current Voltayes


| Guatemala | 220 | (b) | 110/220 | 230/400 | 60 | 50 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Haiti | 440/500 |  | 115 | 110/190, 220/230, | 60 | 50 |
|  |  |  |  | 380, 440/500. |  |  |
| Honduras. | 120/220 | (b) | 110/220 | (b) | 60 |  |
| Mexico. |  | (b) | 110/125 ${ }^{\text {a }}$ - | 115, 120, 216, 220 | 60 | 50 |
| Netherlands West Indies: |  |  |  |  |  |  |
| Aruba | (b) | (b) | 115/120 | 110/220 | 60 | (b) |
| Curacao | (b) | (b) | 125 a | 220 | 50 | (1) |
| Newfoundland | (b) | (b) | 110/220 | (b) | 60 | (b) |
| Nicaragua. | 110/125. | (b) | 110/220 | (b) | 60 | (b) |
| Panama, Republic. | (b) | (b) | 110/220 | (b) | 60 | 50 |
| Panama Canal Zone. | (b) | (b) | 110 | (b) | 25 | (b) |
| Puerto Rico. | (b) | (b) | 115/230 | 120/240, 220/440 | 60 | (b) |
| El Salvador- | 110 | (b) | 110/220 | (b) | 60 | (b) |
| Virgin Islands | (b) | (b) | 120/240 | (b) | 60 | (b) |
| South America: |  |  |  |  |  |  |
| Argentina | 220 | 235, 380, 550 | 220 - | 225/390, 380, 440_.-- | 50 | 25, 60 |
| Bolivia | 110/220. | (b) | 110/220 | 127, 230, 240 | 50 | 60 |
| Brazil | 220 | (b) | 120/220 | 110, 115, 127 | 50 | 60 |
| Chile | 220 | 240 | $220{ }^{\text {a }}$ | 110, 380-.----.---- | 50 | 60 |
| Colombia |  | (b) | 110/220 | $\begin{aligned} & 115,150,230,260 \\ & 380 . \end{aligned}$ | 60 | 50 |
| Ecuador | 220 | (b) | 110/220 | 380 | 60 | 50 |
| Guiana, British.- | (b) | (b) | 115/230 | 110/220 | 50 | 60 |
| Guiana, Dutch (Surinam). | (b) | (b) | 125 --- | 220, 440 | 50 | 60 |
| - Guiana, French.... | (b) | (b) | 110 | (b)_- | 50 | (b) |
| Paraguay | 220 | (b) | 220 | (b) | 50 |  |
| Peru- | 220 | 110 | 220 - | $\begin{aligned} & 110,115,230,240, \\ & 380 / 500 . \end{aligned}$ | 60 | 50 |
| Uruguay | (b) | (b) | 220 |  | 50 | -(b) |
| Venezuela | (b) | (b) | 110/220 | 120, 240 | 50 | 60 |

See footnotes at end of table.

T'able 94. Worldwide Direct-Current and Alternating-Current Vollages-Continued

| Continunt and country | Direct-current voltage |  | Alternating-current voltage |  | Froquency |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Prevailug | Other | Prevalling | Other | Prevailing | Other |
| Europe: |  |  |  |  |  |  |
| Albania | 125 | 150 | $220=$ | $125,150,380$------- | 50 | (b) |
| Austria_ | 220 | $110,440,550$, and others. | 220/380 = | $\begin{aligned} & 125 / 220,110 / 220 \\ & 125,120,110 \\ & \text { aud others. } \end{aligned}$ | 50 | (b) |
| Azores | 220 | (b) | (b) | (b)--------------- | 50 | (b) |
| Belgium. | 110 | 220/440---------.- | 220 | $\begin{aligned} & 110,127,135,190 \\ & 380 . \end{aligned}$ | 50 | (b) |
| Bulgaria.--- | 220 | 440 | 220 - | 120, 150, 380_...-..- | 50 | (b) |
| Czeehoslovakia_ | 110/220. | $120,150,440$, and others. | $220{ }^{\text {a }}$ | $110,115,127,380$ and others. | 50 | 42 |
| Denmark | 220 | 110, 440,550_---... | $220^{\text {a }}$ | 110, 120, 208, $380 \ldots$ | 50 | (b) |
| Finland.- | 120. | 220-------------- | 220/380 ${ }^{\text {a }}$ | $\begin{aligned} & 110,120,208,115 \\ & 127,190 . \end{aligned}$ | 50 | (b) |
| France------ | 110/220 | $\begin{aligned} & 120,190,380,440 \\ & 550 . \end{aligned}$ | 127/220 ${ }^{\text {a }}$-- | $\begin{aligned} & 110 \text { to } 120,150, \\ & 190,200,208,380 . \end{aligned}$ | 50 | 25 |
| Germany ----- | 220 | 110, 440, und others | 220/380 | 110 to 127 and others. | 50 | 25 |
| Gibraltar | 440 | (b) | 240 |  | 50 | (b) |
| Greeee | 220 | 110, 440---------- | 127 | 110, 150, 220, 380 - | 50 | 25, 42 |
| Hungary | 220 | 110, 120 | $220^{\text {a }}$ | $110,115,120$, and others. | 50 | 42 |
| Iceland | (1) $-\ldots-{ }^{----1}$ | (b)---------------- | 220 | (1) ---------------- | 50 | (b) |
| Ireland. | 220 -- |  | $220{ }^{\text {a }}$ | 200, 380----------- | 50 | (b) |


| Italy | 220 | $110,150,380,440$ $550, \text { and others. }$ |
| :---: | :---: | :---: |
| Luxembourg. | 110, 220._ | (b) .--- - |
| Malta | (b) | (b) |
| Monaco_ | (b) | (1) |
| Netherlands. | 220 | 127 |
| Norway | 220 | 110, 440 |
| Poland | 220 | 110, 500, 600 |
| Portugal | 220. | 440. |
| Rumania | 220, 220/440 ${ }^{\text {a }}$ | 110, 120, 150 |
| Spain. | 110. | $\begin{aligned} & 120,130,150,240 \\ & 220,300 . \end{aligned}$ |
| Sweden.- | 220 | $\begin{aligned} & 110,120,220 / 440 \\ & \text { and others. } \end{aligned}$ |
| Switzerland.- | 220 | $160,440,600$, and others. |
| Trieste | (b) | (b) |
| Turkey. | 220 | 110 |
| Union of Soviet Socialist Republics. | 220 | 115, 250, 440 |
| United Kingdom..- | 230 | 220, 440 |
| Vatican City. | (b) |  |
| Yugoslavia-.--- | 110 | 120. |
| Asia : |  |  |
| Aden. | (b) | (b) |
| Afghanistan. |  |  |
| Arabia | (b) | (b) |
| Bhutan_ | 220․ | 440 |


| 125/220 ${ }^{\text {a }}$ | $\begin{aligned} & 120,127,150,260 \\ & \text { and others. } \end{aligned}$ |
| :---: | :---: |
| 220, $380{ }^{\text {a }}$ |  |
| 105 | 210 |
| 110, 115 | (b) |
| $220^{\text {a }}$ | 127, 380 |
| 220 | $\begin{aligned} & 230,130,110,120 \\ & 150,380 . \end{aligned}$ |
| $220^{\text {a }}$ | 110 to 127 |
| $110^{\text {a }}$ | 190, 220, 380 |
| 110, 220, 220/380 | 190, 208, 380, 550 |
| 110 to $130^{\text {a }}$ | 150, 220, 440, and others. |
| 220/380, 127/220ㄹ...- | 110, 110/190 and others. |
| 220/380, 220, $380^{\text {a }} \ldots$ | $110 / 190,125,145 /$ 250, and others. |
| 220, 380, 500²----. | (b) -------- |
| 220 | 110, 190/380 |
| 110/220. | 380 |
| $230^{\text {a }}$ | 220, 240, 250 |
| 125 | 220 |
| $220^{\text {a }}$ | $\begin{aligned} & 150 \text { to } 127,150 \\ & 190,380 . \end{aligned}$ |
| 230/400 | (b) |
| 220/380 | 230 |
| 110/220/440. | 120/240, 250/433 |
| 120/220. | 380/440 . |


| 50 | (b) |
| :---: | :---: |
| 50 | ( ${ }^{1}$ ) |
| 100 | ( ${ }^{\text {( }}$ ) |
| 42 | (b) |
| 50 | (b) |
| 50 | 25,45 |
| 50 | (b) |
| 50 | (b) |
| 50 | 42 |
| 50 |  |
| 50 | 25 |
| 50 | (b) |
| 42 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | 40,25 |
| 45 | (b) |
| 50 | 42 |
| 50 | (b) |
| 50 | 60 |
| 60 | 50 |
| 60 | (b) |

Table 94. Worldwide Direct-Current and Alternating-Current Voltages-Continued


| Java and Madura | (b) | (b) | 127/220. | 110/190, 220/380. |
| :---: | :---: | :---: | :---: | :---: |
| Sumatra.. | 220 | (b) | 127/220, 127. | 110/190, 220/380. |
| Iran. | 220 | 110 | 220 | 380 |
| Iraq- | 220 | 440 | 220 | 380 |
| Israel | (b) | (b) | 220/380 | 230/400 |
| Japan | 100 | (b) | 100/200 |  |
| Jordan | (b) | (b) | 220/380 | (b) |
| Korea | (b) | (1) | 100/200 |  |
| Lebanon. | (b) | (b) | 110/190. | 220/380 |
| Manchuria | (b) | 225 | 110/220 | (b). |
| Nepal | (b) | (b) | 120/220 | 380/440. |
| Pakistan_ | 220 | (b) | 230/400 | 220, 220/380 |
| Philippincs | (b) | (b) | 220 | 110/220. |
| Syria_- | 110/220. | (b) | 110/220 ${ }^{\text {s }}$ | 200, 115, 190 |
| Thailand (Siam) | 220 | 110, 120, 550 | 110/220 | 220, 230, 380 |
| Turkey | 220 | 110 | 220 | 110, 190/380 |
| Africa: |  |  |  |  |
| Angola | (b) | (b) | (b) | 220/380 |
| Algeria_ | (b) |  | 127/220, 220/380 d | $\begin{gathered} 115 / 200,230 / 400, \\ 500,110 . \mathrm{d} \end{gathered}$ |
| Belgian Congo---- | (b) | (b) | 220/380_ | (b) ---- |
| British West Africa: Gambia_ |  |  | 230 |  |
| Ghana (Gold Coast) | $220{ }^{\text {a }}$ | (b) | 230 | (b) |
| Nigeria----- | (b) | (b) | 230/400 d | (b) |
| Sierra Leone. |  | (b) | 230/400 | (b) |
| British East Africa: |  |  |  |  |
| Canary Islands | None |  | 110, 115 | 190, 220 |
| Kenya_ | (b) | (b) | 415/240 | (b) |
| Mauritius | (b) | (b) | 230 | 400 |
| Tanganyika. | 220 | (b) | 230/400 | (b) |
| Uganda | (b) | (b) | 240/415 | (b) |
| Zanzibar | 220 | (b) | (b) | (b) |


| 50 | (b) |
| :---: | :---: |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| c 50,60 | (b) |
| 50 | (b) |
| 60 | (b) |
| 50 | (b) |
| 50 | 25, 60 |
| 60 | (b) |
| 50 | (b) |
| 60 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 |  |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |
| 50 | (b) |

[^23]Table 94. Worldwide Direct-Current and Alternating-Current Vollages-Continued

| Continent and country | Direct-current voltage |  | Altcrnating-current voltage |  | Frequency |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Prevailing | Other | Prevailing | Other | Prevailing | Other |
| Egypt | 220 ${ }^{\text {a }}$---------- |  |  | $\begin{aligned} & 100 / 220,110 / 220 \\ & 380 . \end{aligned}$ | 50 | 40 |
| Ethiopia (including Eritrea). | (b) -------------- | (b)------------------- | 125/220, $127 / 220^{\text {a }}$ - -- | 220/380.-.---------- | 50 | (b) |
| Federation of Rhodesia and Nyasaland: |  |  |  |  |  |  |
| Northerı Rhodesia_- | (b) -------------- | (b) | 220/380_---------- | (b)-------------------1 | 50 | (b) |
| Nyasaland. | (b) -------------- | (b)----------------- | 230/400_---------- | (b)------------------ | 50 | (b) |
| Southern Rhodesia.-- | (b) | (b) | 220/380, 230/400_- | (b)-------------------1 | 50 | (b) |
| French Cameroons------ | (b) | (b) | 115/200. . . | (b)------------------ | 50 | (b) |
| French Equatorial Africa_ | (b) | (b) | 127/220. | 220/380_---------- | 50 | (b) |
| French West Africa_-.-.- | (b) | (b) | 127/220.----------- | 220/380.----------- | 50 | (b) |
| Liberia------------------ | (b) -------------- | (b)------------------- | 115 | 220 | 60 | (b) |
|  | (b) -------------- | (b) | 125 | 220--------------- | 50 | (b) |
| Madagascar_------------ | (b) | (b)------------------- | 127/220_---------- | (b)-------------------10 | 50 | (b) |
| Morocco (southern zone) -- | (b)-------------- | (b)------------------ | 115/200.-.--------- | $\begin{aligned} & 230 / 400,110 / 190 \\ & 500 . \end{aligned}$ | 50 | (b) |
| Morocco (northern zone) - - | (b) -------------- | (b) | 127/220_----------1 | (b) | 50 | (b) |
| Morocco (Tangicr zone) - | (b) | (b) | $110 / 190$ | (b) ----------------- | 50 | (b) |
| Mozambique_----------- | 220 | 240, 250, 480, 550 $\ldots$ | 220/380_---------- | $\begin{gathered} 110 / 190,120,220 / \\ 440,230,240 . \end{gathered}$ | 50 | (b) |
| Seychelles Islands_------ | 220-.------.-.- | (b)-------------------1 | (b)-------------------1 | (b)----------------- | (b) | (b) |
| Sudan-----------------1- | 500.-.---------- | (b) | 240/415.-.---------- | $230$ | 50 | (b) |
| Trust Tcrritory of Somaliland. | 120-_---------- | (b)------------------ | 230----------------- | 127/220, 220/230 $\ldots$ | 50 | (b) |
| Tunisia_----------------- | (b)-------------- | (b)------------------ | 115/200_-.-------- | $\begin{aligned} & 110 / 190,220 / 380 \\ & 230 / 400 . \end{aligned}$ | 50 | (b) |



- Indlcates prevailing voltage-current combination.
${ }^{6}$ Indicates, as a rule, that no further researeh has been performed, sinee prevallong voltage and frequency have been indicated.
- Southern Japan, 50. Northern Japan, 60.
diprevailing voltages in Algeria are $220 / 380$ where possible, 127,220 elsewhere. The 110, 115/200, and $230 / 400$ voltages are being changed to the prevailing standards. The 500 voltage is used for tramways and for rural distribution.
Note. 125/250 Indileates that voltiges are associated. This has been added where sources Indicaterl such condition.


Figure 50. Single-phase, three-wire system.
(1) Voltages. The voltage between the two hot wires equals the sum of the voltages between the neutral and each hot wire. Usually, the voltage between the two hot wires is twice the voltage between the neutral and either hot wire.
(2) Currents. The current in the neutral wire equals the difference between the currents in the hot wires, as shown in figure 51. Current flows in the neutral wire in the same direction as the current in the hot wire carrying the smaller current. If total watts of load connected between the neutral and the two hot wires are equal, the loads are balanced. Under this condition, desirable in electric distribution systems, the current in one hot wire equals the current in the other and no current flows in the neutral.

## 118. Two-Phase Systems

The two-phase system has two single-phase currents having a difference in phase of $90^{\circ}$. It is sometimes called "quarter-phase system." The currents are distributed on the three-wire, four-wire, or five-wire system. This system is not in common usage except in certain localities. Further information may be obtained from the American Electricians' Handbook.

## 119. Three-Phase Systems

A three-phase system is three single-phase systems interlocked so the current in each phase reverses at a different instant than the current in either of the other two phases. Three-phase systems using


Figure 51. Current in neutral wire.
three-phase wires and one neutral wire provide a flexible means of obtaining both lighting and power from the same eircuit and are commonly used. When power only is required the neutral may be omitted. Three-phase systems are better suited than single-phase systems to heavy loads, especially large motors. Figure 52 shows a typical three-phase four-wire systent.
a. Voltages. Two voltages are available simultaneously from a three-phase four-wire system, the phase-to-neutral voltage and the phase-to-phase voltage.
(1) Phase-to-neutral voltage is the voltage between any phase wire and the nentral.
(2) Phase-to-phase voltage is the voltage between any two phase wires. Plase-to-plase voltage equals 1.73 multiplied by the phase-to-neutral voltage.
b. Currents. As in the single-phase system, the loads between the neutral and each phase wire are balanced to reduce eurrent in the neutral to a minimum. A perfectly balanced three-plase system carries equal currents in the phase wires and no current in the neutral.

## 120. Comparison of Systems

Systems are identified by the number of phases and wires and the voltages between wires. For example, in the single-phase three-wire


Figure 52. Three-phase four-wire system.
system, the voltage is 120 volts from hot wire to neutral, and 240 volts betwcen hot wires. This notation is abbreviated $1 \phi 3 \mathrm{w} 120 /$ 240 v . The three-phase four-wire system shown in figure 52 is abbreviated $3 \phi 4 \mathrm{w} 127 / 220 \mathrm{v}$. Standard electrical symbols are given in detail in TM 5-680.

## 121. Electric-Power Requirements

a. General. Predetermine the maximum demand in kilowatts and the average consumption of energy in kilowatt hours when sclecting a suitable power supply, specifying the proper equipment, and computing the cost of electricity.
b. Maximum Demand. The most accurate means of estimating the demand is to determine the connected load and apply suitable diversity factors. These factors are based on experience with projects similar in character and size to that under consideration. A breakdown of large projects and a classification of the types of service required may be helpful in estimating the total maximum demand and in applying the data obtained from other projects containing facilities of similar nature but not necessarily of the same size and composition. In general, the maximum 30 -minute demand for the entire electrical system at posts, camps, and airfields will be approximately 30 percent of the total connected load, and at storage depots will be approximately 200 kilowatts per million square feet of ware-
house area. For industrial plants, the maximum demand should be determined from data furnished by the using service. On a per capita and bed basis, the following demands will be sufficiently accurate for preliminary estimating purposes:

| Army camps. | 0.3 kw . per capita |
| :---: | :---: |
| Air Force tact | 0.3 kw . per capita |
| Air Force strategie bascs | 0.3 kw . per capita |
| Research and development | 1.3 kw . per capita |
| Technical schools | 0.6 kw. per capita |
| Repair schools | 1.5 kw . per capita |
| Hospitals | 2.0 kw. pcr bed |

In applying the above figures to a specific project, special applications must be considered. Where other than normal loads are to be supplied, allowances must be made for the demands that will be imposed by these loads.
c. Consumption. The average monthly consumption should be computed by multiplying the maximum demand by a suitable load factor and by the number of hours the facility will be in operation during the month. The load factor will usually be between 30 and 45 percent at posts, camps, airfields, and storage depots. For instance, at an Army post having a total connected load of 8,000 kilowatts, the estimated maximum demand would be $8,000 \times 0.30=2,400$ kilowatts. Using a load factor of 45 percent, the estimated average monthly consumption would be $2,400 \times 0.45 \times 720=777,600$ kilowatt-hours. Similarly, using the per capita basis, at an Army post having an authorized strength of 8,000 men, the estimated maximum demand would be $8,000 \times 0.3=2,400$ kilowatts. Again using a load factor of 45 percent, the estimated average monthly consumption would be $2,400 \times 0.45 \times 720=777,600$ kilowatt-hours.

## 122. Transformers

a. General. A transformer receives electrical energy from one circuit and transfers it to another circuit by magnetic action. The circuit from which energy is received is called the primary; the receiving circuit is the sccondary. Usually the primary and secondary circuits are at different voltages. An elementary transformer consists of a primary and a secondary coil surrounding an iron core. Alternating current in the primary coil produces an alternating magnetic field in the iron core. A voltage is induced in the secondary coil by the alternating field.
b. Substation Transformers. Substation transformers should be of the outdoor type and of applicable self-cooled rating selected from standard tiansformer KVA ratings.
(1) Standard KVA ratings in single-phase transformers are: 3, 5, $10,15,25,37.5,50,75,100,167,250,333,500,833,1,250$, $1,667,2,500,3,333,5,000,8,333,12,500,16,667,20,000$, 25,000 , and 33,333 .
(2) Standard KVA ratings in three-phase transformers are: 9, 15, $30,45,75,112 \frac{1}{2}, 150,225,300,500,750,1,000,1,500,2,000$, $2,500,3,750,5,000,7,500,10,000,15,000,25,000,37,500$, and 50,000 .
c. Transformers Available in Oversea Depots. The following transformers are currently stocked in oversea depots:
Transformer, Current. Indoor, 25 to 125 Cycles, 1 Phase, Std Current Rating Primary, 200 AMP, Secondary 5 AMP, $13 / 8$ In. Lg, $33 / 4$ In. Dia, 2 Wire Lead Type Terminals.
Transformer, Current, Indoor, 25 to 125 Cycles, 1 Phase, Std Current Rating Primary, 500 AMP, Secondary 5 AMP, 7/8 In. Lg, $3 \frac{3 / 4}{4}$ In. Dia, 2 Wire Lead Type Terminals.
Transformer, Power, Distribution, 3 KVA Continuous, Self- Std Cooled, 55 Deg C Rise Above Ambient Temp, $230 \cdot$ V Nom ASF High, 50 Cycle, Single Phase, 125 V Nom Low, 50 Cycle, Single Phase, Tapped At 115 V And 120 V, 2 Wire Service.
Transformer, Power, Step-Down, Input Primary, 3,000 V, Std 60 Cycles, 1 Phase, Output Secondary, 600 V, 6.6 AMP, 4 Wire Lead Type Terminals.

## 123. Generators

$a$. Table 95 lists the alternating-current and direct-current generators available under the current standardization plan, although other miscellaneous generators still exist in supply channels. These standard generators are capable of supplying the power requirements of all power demands in the field.
$b$. The small alternating-current generators of $0.15-, 0.5-$ and 1.5 -kw output ratings deliver 120 -volts single-phase at frequencies of 60 - or 400 -cycles. The $1.5-\mathrm{kw}, 60$-cycle unit is the most versatile and widely used because its output is adequate for the communications and lighting requirements of small units in the field.
c. The alternating-current generators rated at power outputs of 3-, 5 -, and 10 -kw are all driven with gasoline engines, deliver 60 - or 400 cycle ac, and have a change-over panel which permits connection for $120-208$ volts, 3 -phase, 4 -wire, 120 -volt, 3 -phase, 3 -wure, 120 -volt, single phase, 2 -wire; or $120 / 240$-volt, single phase, 3 -wire operation, each at the full rated kilowatt output. Because of this flexibility and range of power outputs, the 60 -cycle group is quite versatile for general power requirements. The $10-\mathrm{kw}, 60$-cycle is the most versatile since its output is adequate for relatively large loads such as required by small maintenance shops. These generators are skid-mounted and usually covered with a protective housing.
d. Alternating-current generators of larger capacities up to $150-\mathrm{kw}$, are rated at $15-\mathrm{kw}, 45-\mathrm{kw}, 60-\mathrm{kw}, 100-\mathrm{kw}$, and $150-\mathrm{kw}$ and deliver 60 - or 400 -cycle, 3 -phase, 4 -wire power at $120 / 208$ or $240 / 416$ volts.

Output at 50 eyeles is possible at 83 pereent of the rated power output at 60 eycles. In addition to a diescl-driven model in each power rating, the $15-\mathrm{kw}$ and $30-\mathrm{kw}$ units arc available with gasoline-engine drive. The availability of both diesel and gasoline types ean be an important advantage where one or the other fuel may be unobtainable or required. For example, a motor pool requiring only gasoline eould wcll use a gasoline-driven generator for cleetrie power, thereby simplifying fuel supply. The $60-\mathrm{kw}$ diesel-driven generator is probably the most widely used of the larger generators. Beeause the wcight of the $60-\mathrm{kw}$ units represents an easily-handled load for a $21 / 2$-ton truck, wherens larger generator units require a less readily available 5 -ton truek, several $60-\mathrm{kw}$ units are frequently used in parallel to supply large loads.
$e$. The direct-eurrent generators listed are used for such purposes as starting Army aireraft, battery eharging, operation of communieation equipment, and as spare units to start heavy ground equipment. The majority of these units are gasolinc driven and are easily transportable.

## 124. Power Systems

a. Load Estimation.
(1) Connected load. Load estimation covers both the size and location of the items making up the conneeted load. The struetures to be served are identified and marked on an aecurately sealed map of the area. The conneeted load for eaeh structure is then established and tabulated. The conneeted load is the sum of the electric-eurrent requirement of eaeh motor, light, and other eleetrieally operated deviees, expressed in kilovolt-amperes (kv.-a.). One thousand watts in ineandeseent lamps, or 1 horsepower of motor or power load is taken as 1 kv .-a. in estimating the eonneeted load. The conneeted light and power loads for various standard buildings are given in TM 5-302. Connected loads for other struetures may be estimated by comparing floor areas.
(2) Demand load. The conneeted load is converted to demand load by applying a demand factor which is based on experienee. The term load or demand, used alone, means demand load, in kv.-a., required to serve a given connected load. It is less than the conneeted load because all of the lights or other electrie deviees are not in use simultaneously. The demand faetor is the ratio of the maximum demand of a system, or part of the system, under consideration. Demand faetors for military struetures are shown in table 96. Using these, the demand for eaeh structure is computed and tabulated.

Table 95. Family of Engine-Generalors


Table 96. Demand Factors, Military Structures

| Structure | Demand factor |
| :---: | :---: |
| Housing. | 0.9 |
| Aircraft maintenance, facilities_ | 7 |
| Operation facilities. | . 8 |
| Administrative facilities. | . 8 |
| Shops | . 7 |
| Warehouses_ | . 5 |
| Medical facilities | . 8 |
| Theaters | . 5 |
| NAV aids | . 7 |
| Laundry, ice plants, and bakeries | 1. 0 |
| All others | . 9 |

(3) Horsepower limits of electrie motors by systems and voltages are shown in table 97.
(4) Standard horsepower ratings of motors are: $1 / 20,1 / 12,1 / 8,1 / 6,1 / 4,1 / 3$, $\frac{1}{2}, 3 / 4,1,11 / 2,2,3,5,71 / 2,10,15,20,25,30,40,50,60,75,100$, $125,150,200,250,300,350,400,450,500,600,700,800$, $900,1,000,1,250,1,500,1,750,2,000,2,250,2,500,3,000$, $3,500,4,000,4,500$, and 5,000 .
b. Generator Location and Capacity.
(1) Location. To reduce wire requirements, generators are located preferably near points of large demand such as laundries, machine shops, bakeries, ice plants, and X-ray equipment. Generator locations are sclected tentatively by map study of the plotted demands. The size of the area served by each low-voltage generator or transformer depends upon the type and loeation of the demands. In general, small demands such as barracks lighting are served efficiently at distances up to 1,500 feet, moderate demands such as mess structures, up to 1,000 feet. Generators are located on firm ground and along existing roads. Concrete foundations are justified for semipermanent installations of 30 kilowatt or larger generators.
(2) Capacity. Generator eapacity is based on the sum of the demands served but is less than the sum because the peak demands are not simultaneous. The sum of the individual demands, in kv.-a., is multiplied by a generator factor to determine the required generator eapacity in kilowatts. The factor allows for both the power factor (pf) of the generator and for the noneoincidence of demands. Generator factors for theater-of-operations construction are given, in table 98. The diversity factor is discussed in TM 5-765.

Table 97. Horsepower Limits ${ }^{1}$

| System | Voltages | $\underset{\text { Morsepower }}{\text { Minimum }}$ horsepower | Maximum horsepower |
| :---: | :---: | :---: | :---: |
| Alternating current, single phase.......- | 110-115-120 | None | 11/2 |
|  | 220-230-240 | None | 10 |
|  | 440-550 | 5 | 10 |
| Alternating current, two and three-phase - | 110-115-120 | None | 15 |
|  | 220-230-240 | None | 200 |
|  | 440-550 | None | 500 |
|  | 2200 | 40 | None |
|  | 4000 | 75 | None |
|  | 6600 | 400 | None |
| Direct current | 115 | None | 30 |
|  | 230 | None | 200 |
|  | 550-600 | 1/2 | None |

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(3) Number of generators. Enough excess generator capacity is provided to supply the maximum demand with the largest generator out of service. In small systems, generators are preferably of the same size and type, for interchangeability and to reduce the requirements for spare parts. In larger systems, generators of different sizes are justified to permit more efficient operation. For example, if a 100 -kilowatt lighting demand is served by one 30 -kilowatt, one 70 -kilowatt, and one 100 -kilowatt generator, any one generator can be out of service at any time; and the 30-kilowatt generator will probably supply the entire demand in daytime hours.
(4) Interconnection. Generator locations in hospital areas and refrigeration warehouse areas are usually interconnected in insure uninterrupted service. Interconnections require additional copper and are not justified except in hospital and refrigeration areas. If the supply of generators does not permit either interconnection or standby capacity as described in (3) above, the operating rooms and one or two lights per ward are wired on a special circuit to a small emergency generator.
c. Transformer Location and Capacity. Transformers are required wherever the utilization voltage differs from the transmission or distribution voltage. Their location is influenced by the same factors which affect generator locations ( $b(1)$ above). The proper transformer capacity in kv.-a. is the same as the full demand in kv.-a.

Table 98. Generator Factors, Theater-of-Operations Construction

| Type of load | Oenerator factor |
| :---: | :---: |
| Lighting. | 1. 00. |
| Predominantly lighting with some motors | 95 |
| Lighting with ranges and water heaters. | . 95 |
| Lighting and motors about equal | 90. |
| Predominantly motors with some lighting | 85 |
| Motors.--------- | 80 |

(without reduction as in the case of generators). In selecting and locating transformers for lighting loads in military housing areas, a frequently used combination is $10 \mathrm{kv} .-\mathrm{a}$. trausformer distributing through three No. 6 conductors carrying single-phase $120 / 240$ volt current.
d. Line Location. Normally electric distribution systems are of the radial type; lines radiate from generators or substations toward loads, branching and rebranching until all areas are served. The alternative is the ring type system in which the main distribution line forms a closed loop. The ring type normally distributes with less voltage drop but requires more time and material to construct. Lines are normally overhead. Lines carrying voltages above 240 are supported on poles (T.M 5-680C); those carrying 120-240 volts are supported on poles or on masts or insulators attached to buildings.

## 125. Selecting Wire Sizes

a. Requirements. Electric conductors must be large enough to carry the current without heating unduly and without excessive voltage drop. Except for very short lines, the latter requirement is usually the controlling one.
b. Current-Carrying Capacity. Table 99 gives data on current capacities, based on room temperatures of $30^{\circ} \mathrm{C}$. $\left(86^{\circ} \mathrm{F}\right.$.). Table 100 gives correction factors for temperatures over $40^{\circ} \mathrm{C}$. ( $104^{\circ} \mathrm{F}$.). See also tables 101, 102, 103, and 104.
c. Voltage drop.
(1) Allowable drop. The voltage drop is the total loss of voltage from the generator (or transformer or substation at which voltage is controlled) to the lights or motors. Part of the drop occurs in the distribution system (mains), part in the wires from the service entrance to the panel board (fceders), and part in the wires from the panel board to the outlet (branches). Electric wiring and distribution systems are planned for a total drop not in excess of 8 percent for lighting and 5 percent for power. Distribution is shown in table 105.
(2) Drop in distribution lines. Voltage drop is diffieult to compute but is obtained aecurately enough for wiring layouts from the eharts in figures 53 through 57. A separate ehart is given for each voltage and type of cireuit normally used in military systems. The upper scales of load and pereent drop are used for heavier loads; the lower scales for light loads. Although drawn for 60 -cycle current at various wire spaeings, the charts may be used safely for 50 -cycle current at the same spacings. In addition to the line voltage drop, a drop of one volt is added for eaeh standard step-down transformer which forms a part of any line between an initial known voltage and a final load.
(3) Voltage drop and wire sizes in branch circuits. Table 106 gives the wire sizes required for 115 -volt eircuits of various lengths of run, based on a drop of not more than two volts between the panel board and the outlets.

Table 99. Allowance Current Carrying Capacities of Conductors in Amperes for Not More Than Three Conductors in Raceway or Cable (Based on Room Temperature of $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.) (See table 100)

| A | B (note 2) | C | D | E | F | G |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Size AWG or MCM |  | Rubber type RH type RTI-RW (see note 1) type RHW | Paper | Asbestos varnishedcambrie types AVA, AVL | lmpregnated asbestos types Al (14-8) AlA | Asbestos types A (14-8), AA |
|  | Rubber types R, RW, RU, RUW (14-2) |  | Thermoplastic asbestos type TA |  |  |  |
|  | $\begin{aligned} & \text { Type RIl- } \\ & \text { R } W \text { (sce } \\ & \text { note 1) } \end{aligned}$ |  | $\begin{aligned} & \text { Var-Cam } \\ & \text { type V } \end{aligned}$ |  |  |  |
|  | Thermoplastic types T, TW |  | asbestos <br> Var-Cam <br> type AVB |  |  |  |
|  |  |  | MI eable |  |  |  |
| 14- | 15 | 15 | 25 | 30 | 30 | 30 |
| 12. | 20 | 20 | 30 | 35 | 40 | 40 |
| 10. | 30 | 30 | 40 | 45 | 50 | 55 |
| 8----- | 40 | 45 | 50 | 60 | 65 | 70 |
| 6. | 55 | 65 | 70 | 80 | 85 | 95 |
|  | 70 | 85 | 90 | 105 | 115 | 120 |
| 3.---- | 80 | 100 | 105 | 120 | 130 | 145 |
| 2 | 95 | 115 | 120 | 135 | 145 | 165 |
| 1--.-. | 110 | 130 | 140 | 160 | 170 | 190 |
| 0....... | 125 | 150 | 155 | 190 | 200 | 225 |
| 00_-..-- | 145 | 175 | 185 | 215 | 230 | 250 |
| 000....- | 165 | 200 | 210 | 245 | 265 | 285 |
| 0000.-. - | 195 | 230 | 235 | 275 | 310 | 340 |
| 250.-.-- | 215 | 255 | 270 | 315 | 335 | --------- |
| 300.-.-. | 240 | 285 | 300 | 345 | 380 | ------- |

See notes at end of table.

Table 99-Continued

| A | B (note 2 ) | C | D | E | F | G |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Size AWG or MCM |  | Rubber type RH type RH-RW (sce note 1) type RHW | Paper | Asbestos varnishedcambric types AVA, AVL | Impregnated asbestns types AI (14-8) AIA | Asbestos <br> types A <br> (14-8), AA |
|  | Rubber ty pes R,RW, RU, RUW (14-2) |  | Thermoplastic asbestos type TA |  |  |  |
|  | $\begin{gathered} \text { Type RHI- } \\ \text { RW (see } \\ \text { note 1) } \end{gathered}$ |  | $\begin{aligned} & \text { Var-Cam } \\ & \text { type } V \end{aligned}$ |  |  |  |
|  | $\begin{aligned} & \text { Thermoplastic } \\ & \text { types T, TW } \end{aligned}$ |  | asbestos <br> Var-Cam <br> type AVB |  |  |  |
|  |  |  | MI cable |  |  |  |
| 350 | 260 | 310 | 325 | 390 | 420 | -- |
| 400. | 280 | 335 | 360 | 420 | 450 | ------ |
| 500 | 320 | 380 | 405 | 470 | 500 | -----. |
| 600 . . . - | 355 | 420 | 455 | 525 | 545 | - - - - - - |
| 700_- - | 385 | 460 | 490 | 560 | 600 | ------- |
| 750-...- | 400 | 475 | 500 | 580 | 620 | ------- |
| 800-. - - | 410 | 490 | 515 | 600 | 640 | ----- |
| 900-- - - | 435 | 520 | 555 |  |  |  |
| 1000_- - | 455 | 545 | 585 | 680 | 730 |  |
| 1250... | 495 | 590 | 645 |  |  |  |
| 1500.-. | 520 | 625 | 700 | 785 |  |  |
| 1750-- - | 545 | 650 | 735 |  |  |  |
| 2000 | 560 | 665 | 775 | 840 | --------- |  |

Note 1. If type RF-RW rubber-insulated wire is used in wet locations the allowable current carrying capactios will be that of column $C$, and if used in dry locations, the current carrying capacities will be that of column $D$.

Note 2. Insulation type and description.

| Type | Description |
| :--- | :--- |
| R | code-grade rubber compound |
| RW | moisture-resistant rubber compound |
| RU | latex-rubber compound |
| RUW | latex-rubber, moisture-resistant compound |
| RII-RW | bcat-and moisture-resistant rubber compound |
| RH | heat-resistant rubber compound |
| RHW | heat- and moisture-resistant compound |
| T | thermoplastic covered for dry locations |
| TA | thermoplastic and asbestos-covered for switchboard wiring |
| TW | thermoplastic-covered for moist locations |
| MI | mineral-insulated, copper-shcathed for gencral use and special high-temperaturc locations |
| A | non-impregnated, all-asbestos, w/o asbestos outcr braid |
| AA | non-impregnated, all-asbestos, with asbestos outer braid |
| AI | impregnated, all-asbestos; w/o asbestos outer braid |
| AIA | impregnated, all-asbestos; with asbestos outcr braid |
| AVA | impregnated-asbestos and varnished-cambric with asbestos braid |
| AVB | imprcgnated-asbestos and varnished-cambrlc, flame-resistant cotton braid |
| AVL | impregnated-asbestos and varnished-cambric, outer asbcstos braid, lcad shcathed |
| V | varnished-cambric |

Table 100. Correction Factors for Various Room Temperatures Over $40^{\circ} \mathrm{C} .\left(104^{\circ} \mathrm{F}\right.$.)

| ${ }^{\circ} \mathrm{C}$. | ${ }^{\circ} \mathrm{F}$. | B | C | D | E | F | G |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 40 | 104 | 0.82 | 0. 88 | 0. 90 | 0. 94 | 0. 95 |  |
| 45 | 113 | . 71 | . 82 | . 85 | . 90 | . 92 | - - |
| 50 | 122 | . 58 | . 75 | . 80 | . 87 | . 89 | -- |
| 55 | 131 | . 41 | . 67 | . 74 | . 83 | . 86 | -- |
| 60 | 140 | --- | . 58 | . 67 | . 79 | . 83 | 0.91 |
| 70 | 158 |  | . 35 | . 52 | . 71 | . 76 | . 87 |
| 75 | 167 |  |  | . 43 | . 66 | . 72 | . 86 |
| 80 | 176 |  |  | . 30 | . 61 | . 69 | . 84 |
| 90 | 194 |  |  |  | . 50 | . 61 | . 80 |
| 100 | 212 |  |  |  |  | . 51 | . 77 |
| 120 | 248 |  |  |  |  |  | . 69 |
| 140 | 284 |  |  |  |  |  | . 59 |
|  |  |  |  |  |  |  |  |

Note. Columns B to G refer baek to table 99.
Table 101. Allowable Current-Carrying Capacities of Insulated Copper Conductors in Amperes
(Not more than three conductors in raceway or cable or direct burial (based on room temperature of $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.))


See footnotes at end of table.

Table 101. Allowable Current-Carrying Capacities of Insulated Copper Conductors in Amperes-Continued


Correction Factors, Room Temperatures over $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.


[^24]Table 102. Allowable Current-Carrying Capacities of Insulated Copper Conductors in Amperes

Single Conductor in Free Air
(Based on room temperature of $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.)

| $\begin{gathered} \text { Size } \\ \text { AWG } \\ \text { MCM } \end{gathered}$ | Rubber type $R$ type RW | $\begin{gathered} \text { Rubber } \\ \text { type } \\ \text { RII } \end{gathered}$ | Thermoplastic asbestos type TA | $\begin{gathered} \text { Asbestos } \\ \text { Var-Cam } \\ \text { type } \\ \text { type } \\ \text { AVD } \end{gathered}$ | $\begin{gathered} \text { Impreg- } \\ \text { nated } \\ \text { asbestos } \\ \text { type } \\ \text { AI } \\ (14-8) \\ \text { type } \\ \text { ADA } \end{gathered}$ | $\begin{aligned} & \text { Asbestos } \\ & \text { type A } \\ & \text { (14-8) } \\ & \text { type } \\ & \text { AA } \end{aligned}$ | Slowburning sBe |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{gathered} \text { type RU } \\ \text { type RU } \\ (14-2) \end{gathered}$ | $\underset{(14-2)}{R}$ | $\begin{gathered} \text { Var-Cam } \\ \text { type } V \end{gathered}$ |  |  |  |  |
|  | type RH-RW see note <br> 4 a | RH-R ${ }_{\text {ty }}$ see note 4 a | $\begin{gathered} \text { asbestos } \\ \text { Var-Cam } \\ \text { type } \\ \text { AVB } \end{gathered}$ |  |  |  | weather proof type WP |
|  | thermo- | type. | M11 cable |  |  |  |  |
|  | $\begin{aligned} & \text { praste } \\ & \text { type Ty } \\ & \text { type Tw } \end{aligned}$ |  | RHIM (') |  |  |  |  |
| 14 | 20 | 20 | 30 | 40 | 40 | 45 | 30 |
| 12 | 25 | 25 | 40 | 50 | 50 | 55 | 40 |
| 10 | 40 | 40 | 55 | 65 | 70 | 75 | 55 |
| 8 | 55 | 65 | 70 | 85 | 90 | 100 | 70 |
| 6 | 80 | 95 | 100 | 120 | 125 | 135 | 100 |
| 4 | 105 | 125 | 135 | 160 | 170 | 180 | 130 |
| 3 | 120 | 145 | 155 | 180 | 195 | 210 | 150 |
| 2 | 140 | 170 | 180 | 210 | 225 | 240 | 175 |
| 1 | 165 | 195 | 210 | 245 | 265 | 280 | 205 |
| 0 | 195 | 230 | 245 | 285 | 305 | 325 | 235 |
| 00 | 225 | 265 | 285 | 330 | 355 | 370 | 275 |
| 000 | 260 | 310 | 330 | 385 | 410 | 430 | 320 |
| 0000 | 300 | 360 | 385 | 445 | 475 | 510 | 370 |
| 250 | 340 | 405 | 425 | 495 | 530 | ------- | 410 |
| 300 | 375 | 445 | 480 | 555 | 590 | ------- | 460 |
| 350 | 420 | 505 | 530 | 610 | 655 | ------- | 510 |
| 400 | 45.5 | 545 | 575 | 665 | 710 | ------- | 555 |
| 500 | 515 | 620 | 660 | 765 | 815 | -------- | 630 |
| 600 | 575 | 690 | 740 | 855 | 910 | ----- | 710 |
| 700 | 630 | 755 | 815 | 940 | 1, 005 | ------ | 780 |
| 750 | 65.5 | 785 | 845 | 980 | 1,045 | ------- | 810 |
| 800 | 680 | 815 | 880 | 1, 020 | 1, 085 | ------- | 845 |
| 900 | 730 | 870 | 940 |  |  | -- | 905 |
| 1, 000 | 780 | 935 | 1, 000 | 1, 165 | 1, 240 | ------- | 965 |
| 1,250 | 890 | 1, 065 | 1,130 |  | ----- |  | ----- |
| 1,500 | 980 | 1, 175 | 1,260 | 1, 450 |  |  | 1,215 |
| 1, 750 | 1, 070 | 1, 280 | 1,370 |  |  | --- |  |
| 2,000 | 1, 155 | 1, 385 | 1,470 | 1, 715 | --- | ----- | 1,405 |

See footnotes at end of table.

Table 102. Allowable Current-Carrying Capacities of insulated Copper Conductors in Amperes-Continued

Correction Factors, Room Temperatures over $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.


See notes, following table 104.
i The eurrent-earrying eapaeities for type RHH conductors for sizes AWG14, 12, and 10 shall be the samo as designated for type RII eonductors in this table.

Table 103. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes
(Not More than Three Conductors in Raceway or Cable or Direct Burial (Based on room temperature of $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.))

| SizeAWGMCM | Rubbertype R,RW, RU,RUW(12-2), | Rubber <br> type <br> RH <br> RUH <br> $(14-2)$ | Thermoplastic asbestos type TA | Asbestos Var-Cam type AVA type AVI. | Impregasbestos type (14-8) type | Asbesto $\underset{(14-8)}{\text { type A }}$ type AA |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Var-Cam |  |  |  |
|  |  |  | asbestos |  |  |  |
|  | thermoplastic type ${ }^{T}$ |  | type AVB |  |  |  |
|  |  | type <br> RHW | MI cable |  |  |  |
|  |  |  | RHH ${ }^{\text {i }}$ |  |  |  |
| 12 | 15 | 15 | 25 | 25 | 30 | 30 |
| 10 | 25 | 25 | 30 | 35 | 40 | 45 |
| 8 | 30 | 40 | 40 | 45 | 50 | 55 |
| 6 | 40 | 50 | $55^{\circ}$ | 60 | 65 | 75 |
| 4 | 55 | 65 | 70 | 80 | 90 | 95 |
| 3 | 65 | 75 | 80 | 95 | 100 | 115 |
| *2 | 75 | 90 | 95 | 105 | 115 | 130 |
| *1 | 85 | 100 | 110 | 125 | 135 | 150 |
| *0 | 100 | 120 | 125 | 150 | 160 | 180 |
|  | 115 | 135 | 145 | 170 | 180 | 200 |
| *000 | 130 | 155 | 165 | 195 | 210 | 225 |
| *0000 | 155 | 180 | 185 | 215 | 245 | 270 |
| 250 | 170 | 205 | 215 | 250 | 270 | ---- |
| 300 | 190 | 230 | 240 | 275 | 305 | ------ |
| 350 | 210 | 250 | 260 | 310 | 335 | ------ |
| 400 | 225 | 270 | 290 | 335 | 360 | ------ |
| 500 | 260 | 310 | 330 | 380 | 405 | ------ |
| 600 | 285 | 340 | 370 | 425 | 440 | --- |
| 700 | 310 | 375 | 395 | 455 | 485 |  |
| 750 | 320 | 385 | 405 | 470 | 500 |  |
| 800 | 330 | 395 | 415 | 485 | 520 | - |
| 900 | 355 | 425 | 455 |  |  |  |
| 1,000 | 375 | 445 | 480 | 560 | 600 |  |
| 1, 250 | 405 | 485 | 530 |  | ----- |  |
| 1,500 | 435 | 520 | 580 | 650 | --- |  |
| 1,750 | 455 | 545 | 615 |  |  |  |
| 2, 000 | 470 | 560 | 650 | 705 |  |  |

[^25]Table 103. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes-Continued

Correction Factors, Room Temperatures over $30^{\circ}$ C. $86^{\circ} \mathrm{F}$.


[^26]Table 104. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes

Single Conductor in Free Air (Based on room temperature of $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.)

| $\begin{gathered} \text { Size } \\ \text { AWG } \\ \mathbf{M C M} \end{gathered}$ | $\begin{gathered} \text { Rubber } \\ \text { type R, } \\ \text { RW RU, } \\ \text { RUW } \\ (\mathbf{1 2 - 2}) \end{gathered}$ | Rubber <br> type <br> RM <br> RUH <br> (14-2) | Thermoplastic asbestos type TA | Asbestos Var-Cam type AVA type | Impregnated asbestos type AI (14-8) type AIA | A sbestos type A (14-8) type A. | Slowburningtype SB |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | $\begin{aligned} & \text { Var-Cam } \\ & \text { tspe V } \end{aligned}$ |  |  |  |  |
|  | $\begin{aligned} & \text { type } \\ & \text { RH-RW } \\ & \text { note } 4 \mathrm{a} \end{aligned}$ | RH-RW <br> Note 4a | asbestos Var-Cam |  |  |  | Weatherprool |
|  | thermoplastic typeT, |  | IVB |  |  |  | WP |
|  |  | RHpe | MI cable |  |  |  |  |
|  |  |  | R HF ' |  |  |  |  |
| 12 | 20 | 20 | 30 | 40 | 40 | 45 | 30 |
| 10 | 30 | 30 | 45 | 50 | 55 | 60 | 45 |
| 8 | 45 | 55 | 55 | 65 | 70 | 80 | 55 |
| 6 | 60 | 75 | 80 | 95 | 100 | 105 | 80 |
| $\pm$ | 80 | 100 | 105 | 125 | 135 | 140 | 100 |
| 3 | 95 | 115 | 120 | 140 | 150 | 165 | 115 |
| 2 | 110 | 135 | 140 | 165 | 175 | 185 | 135 |
| 1 | 130 | 155 | 165 | 190 | 205 | 220 | 160 |
| 0 | 150 | 180 | 190 | 220 | 240 | 255 | 185 |
| 00 | 175 | 210 | 220 | 255 | 275 | 290 | 215 |
| 000 | 200 | 240 | 255 | 300 | 320 | 335 | 250 |
| 0000 | 230 | 280 | 300 | 345 | 370 | 400 | 290 |
| 250 | 265 | 315 | 330 | 385 | 415 | ------- | 320 |
| 300 | 290 | 350 | 375 | 435 | 460 | ------- | 360 |
| 350 | 330 | 395 | $\pm 15$ | 475 | 510 | ------- | 400 |
| 400 | 355 | 425 | 450 | 520 | 555 | ------- | $\pm 35$ |
| 500 | 405 | 485 | 515 | 595 | 635 | -------- | $\pm 90$ |
| 600 | 455 | 545 | 585 | 675 | 720 | - | 560 |
| 700 | 500 | 595 | 645 | 745 | 795 | -------- | 615 |
| 750 | 515 | 620 | 670 | 775 | 825 | -------- | 640 |
| 800 | 535 | 645 | 695 | 805 | 855 | ------- | 670 |
| 900 | 580 | 700 | 750 |  |  |  | 725 |
| 1000 | 625 | 750 | 800 | 930 | 990 |  | 770 |
| 1250 | 710 | 855 | 905 |  |  |  |  |
| 1500 | 795 | 950 | 1, 020 | 1, 175 |  |  | 985 |
| 1750 | 875 | 1,050 | 1, 125 |  |  |  |  |
| 2000 | 960 | 1, 150 | 1, 220 | 1, 425 |  |  | 1, 165 |

See footnotes at end of table.

Table 104. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes-Continted

Correction Factors, Room Temperatures over $30^{\circ} \mathrm{C} .86^{\circ} \mathrm{F}$.


Sce notes following table 104.
i The current-carrying eapacities for type RIIH conductors for sizes AWG 12,10 , and 8 shall be the same as designated for type RII conductors in this table.

## Notes to Tables 101-104 <br> (Section references are to the National Electrical Code of 1956)

1. Aluminum conductors. For aluminum conductors, the allowable currentcarrying capacities shall be in accordance with tables 103 and 104.
2. Bare conductors. If bare conductors are used with insulated conductors, their allowable current-carrying capacity shall be limited to that permitted for the insulated conductors of the same size.
3. Application of table. For open wiring on insulators and for concealed knob-and-tube work, the allowable current-carrying capacities of tables 102 and 104 shall be used. For all other recognized wiring methods, the allowable current-carrying capacities of tables 101 and 103 shall be used, unless otherwise provided in this code.

The temperature limitation on which the current-carrying capacities of type MI cable are based, is determined by the insulating materials used in the end seal. Termination fittings incorporating unimpregnated organic insulating matcrials are limited to $85^{\circ} \mathrm{C}$. operation.
4. More than three conductors in a raceway. Tables 101 and 103 give the allowable current-carrying capacity for not more than three conductors in a raccway or cable. If the number of conductors in a raceway or cable is from 4 to 6 the allowable current-carrying capacity of each conductor shall be reduced to 80 percent of the values in tables 101 and 103 . If the number of conductors in a raceway or cable is from 7 to 9 , the allowable current-carrying capacity of each conductor shall be reduced to 70 percent of the values in tables 101 and 103. (Exceptions to the foregoing are specified in sections 3624,3745 , and 7265 .)
4. a. If type RIF-RW rubber insulated wire is used in wet locations the allowable current-carrying capacities shall be that of Column 2 in tables 101 to 104. If used in dry locations the allowable current-carrying capacities shall be that of column 3 in tables 101 to 104.
5. Neutral conductor. A neutral conductor which carries only the unbalanced current from other conductors, as in the case of normally balanced circuits of three or more conductors, shall not be countcd in determining current-carrying capacities as provided for in the preceding paragraph.
(In a 3 -wire circuit consisting of two phase wires and the neutral of a 4 -wire, 3-phase system, a common conductor carries approximately the same current as the other conductors and is not therefore considered as a neutral conductor.
6. Ultimate insulation temperature. In no case shall conductors be associated together in such a way with respect to the kind of circuit, the wiring method employed, or the number of conductors, that the linniting temperature of the conductors will be exceeded.
7. Use of conductors with higher operating temperatures. If the room temperature is within $10^{\circ} \mathrm{C}$. of the maximum allowable operating temperature of the insulation, it is desirable to use an insulation with a higher maximum allowable operating temperature; although insulation can be used in a room temperature approaching its maximum allowable operating temperature limit if the current is reduced in accordance with the table of correction factors for different room temperatures.
8. Vollage drop. The allowable current-carrying capacities in tables 101 to 104 are based on temperature alone and do not take voltage drop into consideration.
9. Overcurrent protection. If the standard ratings and settings of overcurrent clevices do not correspond with the ratings and settings allowed for conductors, the next higher standard rating and setting may be used, but not exceeding $1 \overline{5} 0$ percent of the allowable carrying capacity of the conductor.
10. Deterioration of insulation. It should be noted that even the best grades of rubber insulation will deteriorate in time, so eventually will need to be replaced.

Table 105. Voltage Drop, Distribution Systems

| Circuits | System voltage |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 110 | $115{ }^{\circ}$ | 220 | 230 | 440 | 550 |
|  | Voltage drop in volts |  |  |  |  |  |
| Lighting: |  |  |  |  |  |  |
| Branches_ | 4. 4 | 4. 6 | 8. 8 | 9.2 | ---- |  |
| Mains and feeders, combined-- | -4. 4 | 4. 6 | 8. 8 | 9.2 |  | - |
| Total | 8. 8 | 9. 2 | 17. 6 | 18.4 | ----- |  |
| Power: |  |  |  |  |  |  |
| Branches. | 2. 2 | 2. 3 | 2. 2 | 2. 3 | 4. 4 | 5. 5 |
| Mains and feeders, combined.-- | 3. 3 | 3. 5 | 8.8 | 9.2 | 17. 6 | 22. 0 |
| Total | 5.5 | 5. 8 | 11. 0 | 11.5 | 22. 0 | 27. 5 |

(4) A nomograph for finding voltage drop (approximately) is given in figure 58. Example: to find the size of wire to carry 10 amperes 100 feet with a 2 -volt drop of potential; place a straightedgc on 2 volts and 10 amperes, read .2 ohm at the intersection of the straightedge with the ohms scale; place the straightedge on .2 ohm and 100 feet, read No. 10 gage at the intersection of the straightedge with the A.W.G. scale.

## 126. Typical Electrical Layout for Hospital

A typical electrical distribution layout for a 500 -bed hospital, Standard 3, is shown on figure 59. The load centers are each equipped with two $60-\mathrm{KW}, 3 \phi, 4 \mathrm{~W} 120-208 \mathrm{~V}$ generators.

## 127. Pole Lines

a. General. See TM 5-765 for construction details of overhead distribution systems. In general, pole lines should be installed along strects or roads, wherever practicable, in order to avoid the need for separate poles for street lights. In connection with the selection of pole lengths, allowance should be made for the installation of telephone lines on all distribution poles. These lines are usually installed by the Signal Corps or the local telephone company, but the designer of the distribution system is responsible for the additional space and strength requirements. Specified pole lengths include the section below ground line.
b. Depth. Table 107 gives the depths to which poles of various lengths should be set in soil and in rock. Table 108 gives similar data for the case of rock overlaid with a thin layer of soil.


Figure 63. Vollage-drop and wire-size chart for single-phase two-wire 120-volt circuits.



Figure 55. Voltage-drop and wire-size chart for threc-phase four-wire $127 / 220$ voll circuits.



Table 106. Watts per Circuit



* circular mils $=\frac{\text { Amperes } \times \text { distance in feet } \times 21.6}{\text { voltage drop }}$

Figure 58. Wire sizes and voltage drops.


Figure 59. Typical electrical distribution system in a 500-bed hospital, Standard 9.

Table 10\%. Depth for Setting Pole in Soil or Rock

| Hcight of pole (feet) | Depth of setting (feet) |  |
| :---: | :---: | :---: |
|  | In soil | In rock |
| 20. | 5 | 3 |
| 25 | 51/2 | $31 / 2$ |
| 30. | 51/2 | 4 |
| 35. | 6 | 4 |
| 40 | 6 | 4 |
| 45. | 61/2 | 41.2 |
| 50 | 7 | $41 / 2$ |
| 55 | 7112 | 5 |
| 60. | 8 | 5 |

Table 108. Division of Setting Depth in Feet Between Soil and Rock

| 30-foot pole |  | 40-foot pole |  | 50-foot pole |  | 60-foot pole |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Soil | Rock | Soil | Rock | Soil | Rock | Soil | Rock |
| 0. | 4 | 0 | 4 | 0 | 41/2 | 0 | 5 |
| 1. | 4 | 1 | 4 | 1 | 41/2 | 1 | 5 |
| 2 | 3 | 2 | 3 | 2 | 4 | 2 | $41 / 2$ |
| 3 | 2 | 3 | 2 | 3 | 3 | 3 | 4 |
| 4. | 11/2 | 4 | 11/2 | 4 | $21 / 2$ | 4 | 3 |
|  |  | 5 | 1 | 5 | 2 | 5 | 2 |
|  |  |  |  | 6 | 1 | 6 | 11/2 |
|  |  |  |  |  |  | 7 | 1 |
|  |  |  |  |  |  |  |  |

c. Strength. The class of pole is determined on the basis of its ultimate breaking strength at the ground line as listed in table 109. Poles should have four times the strength required to support the aetual vertical and transverse loading, except when the poles are guyed. The guy should support the entire load in the direction in which it acts, the pole simply acting as a strut. Sce $l$ below for characteristics of guys.

Table 109. Breaking Strength of Classified Poles

| Class | Load, pound force | Class | Load, pound force |
| :---: | :---: | :---: | :---: |
| 1. | 4,500. | 5 | 1,900. |
| 2 | 3,700. | 6 | 1,500. |
| 3. | 3,000. |  | 1,200. |
| 4 | 2,400. | 8 to 10 | Not specified. |

d: Footings. Foundations for vertical loads, ineluding the vertical components of guys, must be adequate to prevent the pole from sinking into the ground. When the area of the butt of a pole is too small to bear the vertical load without sinking, a pole footing of planks or eoncrete is installed undcr the butt. Existing poles need not be reinforced unlcss observed to be sinking. The alinement ehart in figure 60 is uscd to determine adcquatc support for vertical loads in various types of soil. The pole eircumfcrenee at the ground line is used as a measure of bearing area. For example, as shown by the dotted line in the alinement chart, a pole bcaring a vertical load of 8,000 pounds in sandy soil requires a polc footing with a ground-line cireumfcrenee of 45 inches. If the class of pole in use or available for usc has a eireumference smaller than 45 inches, a polc footing similar to that illustrated should be used to provide the necessary bearing area. By laying a straightedge aeross the alinement ehart a third condition ean be determined if any two are known.
e. Pole spacing. Poles are spaced at about 125 feet in a straight pole line. The usual maximum is 150 feet; the minimum about 100 fect. In curves and at corners the spacing is reduced as shown in figure 61. For rural lines (relatively long lines and light loads) spans up to 200 or 250 feet are used; and up to 400 or 500 feet when steel-reinforced aluminum eable is used.
$f$. Wire spacing. Three- and four-wire eircuits are normally earried on poles without crossarms, using strain type insulator elevises spaced as shown in figure 62 .


Figure 60. Alinement chart for pole or pole-footing diameters.


| NOTE. If the "PULL" is less than 5', the spans adjacent to the angle pale may be standard 125' length. If the "PULL" exceeds 5', the spans adjacent to the angle pole shall be reduced to the distonce given in the table. | ANGLEA |  | SPAN FEET | NO OF 6000 \# SIDE GUYS |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | I ARM 6 WIRES | 2 ARMS <br> 12 WIRES | 3 ARMS 18 WIRES |
|  | Less Thon $6^{\circ}$ | Less Than 5 | 125 | None | None | None |
|  | $6^{\circ} \cdot 11^{\circ}$ | $5^{\prime} \cdot 10^{\prime}$ | 115 | None | 1 | 1 |
|  | $11^{\circ} \cdot 15^{\circ}$ | 10' - 13' | 105 | 1 | 1 | 1 |
|  | $15^{\circ} \cdot 22^{\circ}$ | $13^{\prime} \cdot 19^{\prime}$ | 95 | 1 | 1 | 2 |
|  | $22^{\circ}-30^{\circ}$ | $19^{\prime}-26^{\prime}$ | 85 | 1 | 1 | 2 |
|  | Over | Over $26^{\prime}$ | 75 | 1 | 2 | 2 |

Figure 61. Pole spacing and side guys on curves.
g. Wire clearances aboveground. Minimum allowable clearances under various conditions are given in figure 63.
$h$. Wire. Diameters, weights, and resistances of wires normally used in overhead distribution systems are given in tables 110 through 114.
i. Sag. Sags in inches for various wire sizes, stringing temperatures, and span lengths, based on hard- and medium-drawn insulated copper wire, are shown in table 115.
$j$. Tension. The tension in an overhead wire, in parts of the weight of the wire span including any insulation and ice coating, and for various sag ratios is shown in table 116. The table also gives the vertical angle at which the wire leaves the pole, for plotting the vertical and horizontal components of the tension.
k. Loads and ultimate strengths of wire. See TM 5-765 for more complete data on loadings. The National Electrical Safety Code divides the United States into three zones classed as heavy, medium, and light loading areas, respectively, based on the ice and wind loads to be expected on overhead lines. (See figure 64.) The wind loads vary from 4 to 9 pounds per square foot, and the radial thickness of


Figure 62. Wire spacing on poles.
ice on conductors is one-half inch in the heavy zone (coupled with a temperature of $0^{\circ} \mathrm{F}$.), one-fourth inch in the medium zone (at plus $15^{\circ} \mathrm{F}$.) and none in the light zone. Tables 117 to 121 give the loading per foot of conductor for the three loading areas and strength data for conductors ordinarily used at Army installations. The allowable tension is usually taken as one-half the ultimate strength given in the tables.

Table 110. Bare Solid Copper Wire

| Size (AWG) | Diameter (inches) | Weight (pounds per 1,000 feet) | $\begin{aligned} & \text { Resistance (ohms per } \\ & 1,000 \text { feet at } 20^{\circ} \mathrm{C} \text {.) } \end{aligned}$ |
| :---: | :---: | :---: | :---: |
| 4/0.-.--------- | 0. 4600 | 639.8 | 0. 04893 |
| 3/0.-- | . 4096 | 507.3 | . 06170 |
| 2/0. | . 3648 | 402. 4 | . 07780 |
| 1/0 | 3250 | 319.4 | . 09811 |
| 1. | . 2893 | 253.0 | . 1237 |
| 2 | 2576 | 200.6 | . 1560 |
| 3 | 2294 | 159.1 | . 1967 |
| 4. | $20+3$ | 126. 2 | . 2480 |
| 5. | . 1819 | 100. 0 | . 3128 |
| 6. | . 1620 | 79. 35 | . 3944 |
| 7. | . 1443 | 62. 96 | . 4973 |
| 8 | . 1285 | 49. 92 | . 6271 |



Figure 63. Minimum clearances of conductors.
Table 111. Weatherproof Solid Copper Wire

| Size (AWG) | Diameter over insulation (inches) |  | Weight (pounds per 1,000 feet) |  | $\begin{aligned} & \text { Resistance } \\ & \text { (ohms per } 1,000 \\ & \text { feet at } 20^{\circ} \mathrm{C} \text {.) } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Three-braid | Two-braid | Three-braid | Tiwo-braid |  |
| 4/0...-.-. - | 0. 640 | . 609 | 767 | - 723 | 0. 04893 |
| 3/0------- | . 593 | . 562 | 629 | 587 | . 06170 |
| $2 / 0$ | . 515 | . 500 | 502 | 467 | . 07780 |
| $1 / 0$ | . 500 | . 468 | 407 | 377 | . 09811 |
| 1. | . 453 | . 422 | 316 | 294 | . 12370 |
| 2 | . 437 | . 390 | 260 | 239 | . 15600 |
| 3. | . 406 | . 359 | 199 | 185 | . 19670 |
| 4. | . 359 | . 328 | 64 | 151 | 24800 |
| 6. | . 328 | . 296 | 112 | 100 | 39440 |
| 8----.----- | . 296 | . 250 | 75 | 66 | . 62710 |

Table 112. Bare Stranded Copper Wire

| Size (AWG) | Diameter (inehes) | Weight (pounds per 1,000 feet) | Resistance (ohms per <br> 1,000 feet at $20^{\circ} \mathrm{C}$.) | Wires in strand |
| :---: | :---: | :---: | :---: | :---: |
| 4/0. | 0. 5275 | 653. 14 | 0. 04997 | 19 |
| 3/0 | . 4644 | 412. 07 | . 06293 | 7 |
| 2/0 | . 4134 | 406. 98 | . 07935 | 7 |
| $1 / 0$ | . 3684 | 322. 39 | . 10007 | 7 |
| 1. | . 3279 | 255. 45 | . 12617 | 7 |
| 2 | . 2919 | 202. 50 | . 15725 | 7 |
| 3. | . 2601 | 160.60 | . 19827 | 7 |
| 4 | . 2316 | 127. 40 | . 25000 | 7 |
| 6. | 1836 | 80.10 | . 39767 | 7 |

Table 113. Weatherproof Stranded Copper Wire

| Size (AWG) | Dlameter over insulation (inches) |  | Wires in strand | Weight (pounds per 1,000 feet) |  | Resistanee (ohms per 1,000 feetat $20^{\circ} \mathrm{C}$.) at $20^{\circ} \mathrm{C}$.) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Three-braid | Two-braid |  | Three-braid | Two-braid |  |
| 4/0 | 0.812 | 0.687 | 19 | 800 | 745 | 0. 04997 |
| 3/0. | . 734 | . 671 | 7 | 653 | 604 | . 06293 |
| $2 / 0$ | . 687 | . 625 | 7 | 522 | 482 | . 07935 |
| 1/0. | . 640 | . 578 | 7 | 424 | 388 | . 10007 |
| 1 | . 593 | . 531 | 7 | 328 | 303 | . 12617 |
| 2. | . 531 | . 468 | 7 | 270 | 246 | . 15725 |
| 3 | . 468 | . 421 | 7 | 206 | 190 | . 19827 |
| 4. | . 437 | . 390 | 7 | 70 | 155 | . 25000 |
| 6.--------- | . 406 | . 359 | 7 | 115 | 103 | . 39767 |

Table 114. Bare Solid Steel Wire

| Size (BWG) | Approximate diameter (inehes) | $\begin{gathered} \text { Weight } \\ \text { (pounds per } \\ \text { 1,000 feet) } \end{gathered}$ | Current load (amperes) |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 1 | 2.5 | 5 | 10 |
|  |  |  | Resistance (ohms per mile at $20^{\circ} \mathrm{C}$.) |  |  |  |
|  | 0. 238 | 154 | 7. 48 | 7. 59 | 7. 92 | 9. 23 |
|  | 203 | 112 | 10. 15 | 10. 42 | 10. 79 | 12. 47 |
| 8-- | . 165 | 73.5 | 15. 06 | 15. 26 | 15. 71 | 18. 35 |

Table 115. Wire Sag in Inches

| $\begin{aligned} & \text { Wire } \\ & \text { size } \\ & \text { AWG } \end{aligned}$ | $\begin{gathered} \text { String- } \\ \text { ing } \\ \text { temp } \\ { }^{\circ} \mathrm{F} . \end{gathered}$ | Frigid and Temp Zones |  |  |  |  |  |  | Tropical Zones |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Spans |  |  |  |  |  |  | Spans |  |  |  |  |  |  |
|  |  | $100{ }^{\prime}$ | 125' | $150^{\prime}$ | $175{ }^{\prime}$ | $200^{\prime}$ | 250 | $300^{\prime}$ | $100^{\prime}$ | 125' | $150{ }^{\prime}$ | 175' | $200{ }^{\prime}$ | $250{ }^{\prime}$ | $300{ }^{\prime}$ |
| 8.-. - | 30 | 15 | 23 | 36 |  |  |  |  | 8. 5 | 14 | 22.5 | 31 |  |  |  |
|  | 60 | 18 | 37 | 40 |  |  |  |  | 12 | 18 | 27 | 36 |  |  |  |
|  | 90 | 21. 5 | 31 | 44 |  |  |  |  | 15. 5 | 22. 5 | 32 | 41 |  |  |  |
| 6... - | 30 | 8. 5 | 14 | 22 | 31 |  |  |  | 6 | 9 | 14 | 19.5 | 26 |  |  |
|  | 60 | 12 | 18 | 27 | 36 |  |  |  | 8 | 12 | 18 | 24 | 32 |  |  |
|  | 90 | 15. 5 | 22. 5 | 32 | 40 |  |  |  | 11 | 16 | 22. 5 | 29 | 38 |  |  |
| 4--- | 30 | 8. 5 | 14 | 21. 5 | 531 | 43 |  |  | 6. 5 | 9 | 14 | 19 | 26 |  |  |
|  | 60 | 12 | 18 | 27 | 36 | 48 |  |  | 8 | 12 | 18 | 24 | 32 |  |  |
| 2.-. - | 90 | 17 | 22. 5 | 32 | 41 | 54 |  |  | 11.5 | 16 | 22 | 30 | 38 |  |  |
|  | 30 | 8. 5 | 14 | 21. 5 | 5.23. 5 | 30 | 53 | 89 | 6. 5 | 9 | 14 | 17.5 | 21 | 28 | 45 |
|  | 60 | 12 | 18 | 27 | 30 | 36 | 60 | 96 | 8 | 12 | 18 | 22 | 26 | 34 | 52 |
| 1...- | 90 | 17 | 22. 5 | 32 | 35 | 42 | 67 | 103 | 11.5 | 16 | 22 | 27 | 32 | 41 | 60 |
|  | 30 | 8. 5 | 13. 5 | 20. 5 | 522.5 | 26 | 42 | 66 | 5. 5 | 5 | 13. 5 | 16. 5 | 19 | 26 | 38 |
| 1/0-- |  | 12 | 18 | 26 | 28 | 32 | 49 | 72 | 8 | 12 | 18 | 21 | 24 | 31 | 45 |
|  | 90 | 15. 5 | 22. 5 | 31 | 34 | 38 | 56 | 82 | 11.5 | 16 | 23 | 26 | 30 | 38 | 53 |
|  | 30 | 8. 5 | 13. 5 | 20. 5 | 522.5 | 26 | 42 | 66 | 5. 5 | 9 | 14 | 16. 5 | 18 | 24.5 | 34 |
|  |  | 12 | 18 | 26 | 28 | 32 | 49 | 72 | 8 | 12 | 18 | 21 | 23 | 30 | 41 |
| 2/0.-- | 90 | 15. 5 | 22. 5 | 31 | 34 | 38 | 56 | 82 | 11.5 | 16.5 | 23 | 27 | 28 | 36 | 47 |
|  | 30 | 8. 5 | 13.5 | 20 | 22.5 | 25 | 38 | 57 | 5. 5 | 9 | 13.5 | 16 | 17. 5 | 23 | 31 |
| 4/0--- |  | 12 | 18 | 25 | 28 | 31 | 46 | 66 | 8 | 12 | 18 | 20 | 22 | 28 | 37 |
|  | 90 | 16 | 22.5 | 30 | 34 | 38 | 53 | 73 | 11. 5 | 16 | 23 | 25 | 28 | 35 | 45 |
|  | 30 | 8. 5 | 13.5 | 18. 5 | 521 | 24. 5 | 31 | 43 | 5. 5 | 5.5 | 13. 5 | 16 | 16.5 | 20. 5 | 27 |
|  | 60 | 12 | 18 | 24 | 27 | 30 | 38 | 50 | 8 | 12 | 18 | 19 | 21 | 25 | 32 |
|  | 90 | 16 | 22.5 | 29 | 33 | 36 | 46 | 59 | 11.5 | 16 | 23 | 24. 5 | 26 | 31 | 39 |

l. Guys and guy loarls. The ordinary guying of poles at bends in lines is covered in $e$ above. For heavicr loads, dead ends, corners, and the like, find the resultant horizontal load by a parallelogran of forces, determine the guy slope practicable, and select guys from figure 65.
$m$. Crossarms. See TM 5-765 for additional data. All crossarm loads are reduced to an equivalent load on the end pin, horizontally and vertically, and the horizontal unbalance is determined as shown in figure 66. The required crossarm size or any necessary doubling of crossarms is then selected from tables 122 and 123.

## 128. Wire Sizes

Tables 124,125 , and 126 are based upon a voltage drop of about 3 percent.

Table 116. Wire-Sag Tension

| Sag in parts of the span | Sag in decimal parts of span | Tension at pole in parts of the weight of the span of wire | Vertical leavin | of wire ole | Length of wire in parts of span |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Deg. | Min. |  |
| 1/300 | 0. 00333 | 37. 5 | 0 | 46 | ${ }^{1} 1.00$ |
| 1/200 | . 005 | 25. 0 | 1 | 09 | ${ }^{1} 1.00$ |
| 1/150. | .0067 | 18. 8 | 1 | 32 | ${ }^{1} 1.00$ |
| 1/125 | . 008 | 15. 6 | 1 | 50 | ${ }^{1} 1.00$ |
| 1/100. | . 01 | 12. 5 | 2 | 18 | ${ }^{1} 1.00$ |
| 1/80...... | . 0125 | 10.0 | 2 | 52 | ${ }^{1} 1.00$ |
| 1/67.5----- | . 015 | 8.45 | 3 | 23 | ${ }^{1} 1.00$ |
| 1/50.-.-- | . 02 | 6. 27 | 4 | 35 | ${ }^{1} 1.00$ |
| 1/40...... | . 025 | 5. 03 | 5 | 43 | ${ }^{1} 1.00$ |
| 1/35-..-- | . 0286 | 4. 40 | 6 | 31 | ${ }^{1} 1.00$ |
| 1/30 - | . 0333 | 3. 78 | 7 | 36 | ${ }^{1} 1.00$ |
| 1/25. | . 04 | 3. 16 | 9 | 06 | ${ }^{1} 1.00$ |
| 1/20.....-- | . 05 | 2. 55 | 11 | 19 | 1. 01 |
| 1/15----- | . 0667 | 1. 94 | 14 | 55 | 1. 01 |
| 1/10.-.-.-- | . 1 | 1. 35 | 21 | 48 | 1. 03 |
| 1/5-------- | . 2 | . 800 | 38 | 40 | 1. 10 |
| 1/4.-..-.-. | . 25 | . 707 | 45 | 00 | 1. 15 |
| 1/3------- | . 333 | . 625 | 53 | 08 | 1. 25 |
| 1/2------- | . 5 | . 559 | 63 | 26 | 1. 48 |

1 Less than 1.005


Figure 64. Loading map for overhead wires.

Table 117. Solid Copper, Triple-Braid, Weatherproof Wire

| Conductor size AWO | Ultmate strength (pounds) |  |  | Loading (pounds per linear foot of conductor) |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{gathered} \text { Hard } \\ \text { drawn } \\ \text { (ninimum) } \end{gathered}$ | Medium hard drawn(minimum) | Annealed(maximum) | Light loading |  |  | Medium loading |  |  | Heavy loading |  |  |
|  |  |  |  | $\begin{array}{\|c\|} \begin{array}{c} \text { Vertical } \\ \text { (conductor } \\ \text { without } \\ \text { ice) } \end{array} \\ \hline \end{array}$ | Transverse (9ib. wind per square foot on conductor without lce) | Conductor loading ${ }^{1}$ | Vertical (conductor plus 14-in. radtal ice) | Transverse (4lb. wind per square foot on ice-covered conductor) | Conductor loading | Vertical (conductor pius 1ain. radial Icc) | Transverse (4lb. wind per square foot on ice-covered conductor) | Conductor loarling ${ }^{1}$ |
| 4/0_ | 7, 740 | 6,630 | 6, 280 | 0. 767 | 0. 578 | 1. 010 | 1. 084 | 0. 423 | 1. 384 | 1. 557 | 0.590 | 1. 975 |
| 3/0. | 6, 390 | 5, 380 | 4,980 | . 629 | . 533 | . 875 | . 927 | . 403 | 1. 231 | 1. 381 | . 570 | 1. 804 |
| 2/0 | 5, 240 | 4,370 | 3, 950 | . 502 | . 473 | . 740 | . 776 | . 377 | 1. 083 | 1. 205 | 543 | 1. 632 |
| 1/0 | 4, 290 | 3, 540 | 3, 130 | . 407 | . 428 | . 641 | . 662 | . 357 | . 972 | 1. 072 | . 523 | 1. 503 |
| 1 | 3,503 | 2, 870 | 2, 550 | . 316 | . 390 | 552 | . 555 | . 340 | . 872 | . 950 | . 507 | 1. 387 |
| 2 | 2, 850 | 2, 330 | 2, 030 | 260 | . 356 | 492 | 485 | . 325 | . 803 | . 866 | . 492 | 1. 306 |
| 3. | 2, 320 | 1,885 | 1, 606 | . 199 | . 315 | . 423 | . 407 | . 307 | . 730 | 771 | . 473 | 1. 215 |
| 4. | 1, 872 | 1,505 | 1, 274 | . 164 | 293 | . 386 | . 363 | . 297 | . 689 | 717 | . 463 | 1. 164 |
| 6. | 1, 216 | 960 | 801 | . 112 | 251 | . 325 | . 294 | . 278 | . 625 | . 631 | . 445 | 1. 082 |
| 8. | 785 | 612 | 504 | . 075 | 218 | 281 | . 243 | 263 | . 578 | . 566 | . 430 | 1. 021 |
| 10. | 503 | 390 | 330 | . 053 | . 188 | . 245 | . 208 | 250 | . 545 | . 519 | . 417 | 0. 976 |
| 12-------- | 402 | 249 | 207 | . 035 | . 158 | . 212 | . 178 | . 237 | . 516 | . 476 | . 403 | 0. 934 |

${ }^{1}$ Conductor loading per foot as specified in Rule 251, NESC, 5th edition.

Table 118. Stranded Copper, Triple-Braid, Weatherproof Wire

| Conductor size circular mils or AWG | Ultimate strength (pounds) |  |  | Louding (pounds per linear foot of eonduetor) |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\left\lvert\, \begin{gathered} \text { Hard } \\ \text { drawn } \\ \text { minimum) } \end{gathered}\right.$ | $\left\|\begin{array}{c} \text { Medium } \\ \text { hard drawn } \\ \text { (mininuin) } \end{array}\right\|$ | Annealed(maxinuun) | Light louding |  |  | Medium loading |  |  | Heavy loading |  |  |
|  |  |  |  | Vertical (conductor without ice) | Trunsverse (9- <br> lb. wind per scluare fool on conducter without ies) | Conductor loading ' | Vertical (condactor phus lítin. radial ice) | Transverse (41h. wind per square foot on ice-covered conductor) | Conductor loading ${ }^{1}$ | $\left\lvert\, \begin{gathered} \text { Vertical } \\ \text { (conductor } \\ \text { plus thein. } \\ \text { radial ice } \end{gathered}\right.$ | Transverse (1lb. wind per square foot on ice-covered conductor) | Conduetor louling 1 |
| 1000000 | 41,610 | 32,630 | 30,510 | 3. 670 | 1. 275 | 3. 935 | 4. 276 | 0.733 | 4. 559 | 5. 038 | 0.900 | 5.429 |
| 750000 | 31,730 | 24, 840 | 22,880 | 2. 822 | 1. 125 | 3. 088 | 3. 366 | . 667 | 3. 652 | 4. 066 | . .833 | 4. 460 |
| 500000 | 21, 390 | 16, 450 | 15,260 | 1. 894 | . 938 | 2. 163 | 2. 361 | . 583 | 2. 651 | 2. 983 | 750 | 3. 385 |
| 350000 | 14, 380 | 11, 590 | 10, 680 | I. 345 | . 788 | 1. 609 | 1. 749 | . 517 | 2. 053 | 2. 309 | 683 | 2. 718 |
| 250000. | 10,790 | 8, 394 | 7, 628 | . 984 | . 683 | 1. 248 | 1. 346 | . 470 | 1. 646 | 1. 862 | . 637 | 2. 278 |
| 4/0. | 8,696 | 7, 105 | 6,456 | . 800 | 623 | 1. 064 | 1. 136 | . 443 | 1. 440 | 1. 627 | . 610 | 2. 048 |
| 3/0. | 6, 998 | 5,521 | 5, 119 | . 653 | . 563 | . 912 | . 964 | . 417 | 1. 270 | 1. 431 | . 583 | 1. 855 |
| $2 / 0$ | 5, 630 | 4, 409 | 4, 061 | . 522 | 503. | . 775 | 808 | . 390 | 1. 117 | 1. 250 | . 557 | 1. 678 |
| 1/0 | 4, 514 | 3,518 | 3,219 | . 424 | . 465 | . 679 | 695 | . 373 | 1. 009 | 1. 121 | . 540 | 1. 554 |
| 1. | 3, 614 | 2, 810 | 2, 554 | . 328 | . 413 | . 577 | . 578 | . 350 | . 896 | . 981 | . 517 | 1. 419 |
| 2 | 2, 893 | 2, 243 | 2, 107 | . 270 | 383 | . 518 | . 507 | . 337 | . 829 | . 898 | . 503 | 1. 339 |

[^27]Table 119. Bare, Copper Cable

| Conductor size AWG and standing | Ultimate strength (pounds) |  |  |  |  | Loading (pounds per linear foot of conductor) |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Overall $\underset{\text { (inch) }}{\text { diancter }}$ | $\begin{gathered} \text { Cross } \\ \text { sectional } \\ \text { area } \\ \text { (square } \\ \text { incb) } \end{gathered}$ | $\begin{gathered} \text { Hard } \\ \text { drawn } \\ \text { (mini- } \\ \text { mum) } \end{gathered}$ | Medium hard drawn mum) | $\underset{\substack{\text { (maxi- } \\ \text { mum) }}}{\text { Annealed }}$ | Ligbt loading |  |  | Medium loading |  |  | Heavy loading |  |  |
|  |  |  |  |  |  | Vertical (weight of conductor without ice) |  | Conductor loading | Vertical (con- ductor plus p/4-in. radial ice) |  | Conductor loading ${ }^{1}$ | Vertlcal (con- ductor plus yh-lln. radlal ice) | Trans verse (4-1b. wind per square foot on ive-conductor) | Conductor loadlng ${ }^{1}$ |
| 4/0 | $\begin{array}{r} 0.552 \\ .522 \end{array}$ | $\begin{array}{r} \text { 0. } 1662 \\ .1662 \end{array}$ | $\begin{aligned} & 9,483 \\ & 9,154 \end{aligned}$ | $\begin{aligned} & 7,378 \\ & 7,269 \end{aligned}$ | $\begin{aligned} & 6,149 \\ & 6,149 \end{aligned}$ | $\begin{array}{r} 0.6533 \\ .6533 \end{array}$ | $\begin{array}{r} 0.4140 \\ .3915 \end{array}$ | $\begin{array}{r} 0.8234 \\ .8116 \end{array}$ | $\begin{array}{r} 0.9027 \\ .8934 \end{array}$ | 0. 3507 | 1. 1584 | 1. 3076 | 51735073 | $\begin{aligned} & \text { 1. } 6962 \\ & \text { 1. } 6752 \end{aligned}$ |
| 12 strand.-- |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 strand. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3/0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 12 strand | . 492 | . 1318 | 7, 556 | 5, 890 | 4, 876 | . 5181 | : 3690 | . 6861 | 7489 | . 3307 | 1. 0087 | 1. 1351 | . 4973 | 1. 5293 |
| 7 strand. | . 464 | . 1318 | 1,366 | 5, 812 | 4, 876 | . 5181 | . 3480 | . 6741 | . 7402 | . 3213 | . 9969 | 1. 1177 | . 4880 | 1. 5096 |
| 2/0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 strand | . 414 | . 1045 | 5,926 | 4, 641 | 3, 868 | 4109 | . 3105 | 5650 | . 6174 | . 3047 | . 8785 | . 9794 | . 4713 | 1. 3769 |
| 1/0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 strand. | . 368 | . 08289 | 4, 752 | 3, 703 | 3, 066 | . 3257 | . 2760 | 4769 | . 5179 | 2893 | 7832. | . 8656 | . 4560 | 1. 2684 |



[^28]Table 120. Solid Copper, Bare Wire

| Conductor slzc AWG | Ultimate strength (pounds) |  |  |  |  | Loaring (pounds per linear foot of conductor) |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Overall diameter (inch) | $\begin{gathered} \text { Cross } \\ \text { sectional } \\ \text { arca } \\ \text { (square } \\ \text { inch) } \end{gathered}$ | Hard drawn $\underset{\text { mum! }}{\substack{\text { (nlni } \\ \text { mun }}}$ | Medium hard drawn mum) | Annealed (maximum) | Light loading |  |  | Medium loading |  |  | Heavy loading |  |  |
|  |  |  |  |  |  | Vertical (weight of coliwithout ice) | Trans- verse (9-1b. wind per square foot on conductor without ice $)$ | $\begin{gathered} \text { Con- } \\ \text { ductor } \\ \text { loadling } \end{gathered}$ | Vertical (conductor plus y4-in. ice) | Transverse (4-b. wind per square foot on covered conductor) | Conductor loading 1 | Vertical (conductor plus radiai ice) | Transverse (4-lb. wind per square foot on covered ductor) | Conductor load Ing ' |
| 4/0 | 0. 4600 | 0. 1662 | 8, 143 | 6, 980 | 5, 983 | 0. 6405 | 0. 3450 | 0. 7775 | 0. 8613 | 0. 3200 | 1. 1088 | 1. 2376 | 0. 4867 | 1. 6199 |
| 3/0 | . 4096 | 1318 | 6, 772 | 5, 667 | 4, 745 | 5079 | . 3072 | 6436 | 7130 | 3032 | . 9648 | 1. 0737 | . 4699 | 1. 4620 |
| $2 / 0$ | . 3648 | 1045 | 5,519 | 4, 599 | 3, 763 | . 4028 | . 2736 | . 5869 | 5940 | 2883 | 8503 | 9407 | . 4549 | 1. 3349 |
| 1/0 | . 3249 | . 08289 | 4, 517 | 3, 730 | 2, 984 | . 3195 | . 2437 | 4518 | . 4983 | 2750 | 7592 | 8326 | . 4416 | 1. 2325 |
| 1. | . 2893 | 06573 | 3, 688 | 3, 024 | 2, 432 | . 2533 | . 2170 | . 3835 | . 4210 | . 2631 | . 6865 | 7441 | . 4298 | 1. 1493 |
| 2 | . 2576 | . 05213 | 3, 003 | 2, 450 | 1, 929 | . 2009 | 1932 | . 3287 | . 3587 | . 2525 | . 6287 | . 6720 | . 4192 | 1. 0820 |
| 3 | . 2294 | . 04134 | 2, 439 | 1,984 | 1, 530 | . 1593 | 1721 | 2845 | . 3083 | 2431 | . 5826 | . 6128 | . 4098 | 1. 0272 |
| 4 | . 2043 | . 03278 | 1, 970 | 1, 584 | 1, 213 | . 1264 | . 1532 | . 2486 | 2676 | 2348 | . 5460 | . 5643 | . 4014 | 9825 |
| 5 | . 1819 | . 02600 | 1, 591 | 1, 265 | 961.9 | . 1002 | 1364 | . 2193 | 2345 | 2273 | . 5166 | . 5242 | 3940 | . 9458 |
| 6 | . 1620 | . 02062 | 1, 280 | 1, 010 | 762.9 | . 07946 | . 1215 | . 1952 | . 2075 | 2207 | . 4929 | . 4911 | . 3873 | . 9155 |
| 7 | . 1443 | . 01635 | 1, 030 | 806.6 | 605.0 | . 06302 | 1082 | . 1752 | . 1856 | . 2148 | . 4739 | . 4636 | . 3814 | . 8903 |
| 8 | . 1285 | . 01297 | 826.0 | 643.9 | 479.8 | 04997 | . 09638 | 1586 | 1676 | 2095 | . 4583 | . 4408 | . 3762 | . 8695 |
| 9 | . 1144 | . 01028 | 661. 2 | 514. 2 | 380.5 | . 03963 | . 08580 | . 1445 | . 1530 | . 2048 | . 4456 | . 4218 | . 3715 | . 8521 |
| 10 | . 1019 | . 008155 | 529. 2 | 410.4 | 314.0 | . 03143 | . 07643 | 1326 | 1409 | 2006 | . 4351 | . 4058 | . 3673 | . 8373 |
| 11 | . 09074 | . 006467 | 422.9 | 327.6 | 249.0 | . 02492 | . 06806 | 1225 | 1309 | 1969 | . 4264 | . 3924 | 3636 | . 8250 |
| 12 | 08081 | . 005129 | 337.0 | 261. 6 | 197.5 | . 01977 | . 06061 | 1138 | . 1227 | . 1936 | . 4192 | . 3810 | . 3603 | 8144 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

[^29]Table 121. Bare, Copperweld-Copper and Copperweld

|  | Conductor size | Overall diameter (inches) | $\left\|\begin{array}{c} \text { Cross } \\ \text { sectional } \\ \text { arca (square } \\ \text { inches) } \end{array}\right\|$ | Ultimate strength (pounds) | Loading (Ib. per linear ft. of conductor) |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Light Loading |  |  | Medium Loading |  |  | Heavy Loading |  |  |
|  |  |  |  |  | $\begin{array}{\|c} \text { Vertical } \\ \text { (conductor } \\ \text { without } \\ \text { ice }) \end{array}$ | Transverse ${ }^{(9-1 b}$. wind per square foot on conductor icc) | Conductor loading 1 | Vertical (conductor plus $1 / 4$-in. radial ice) | Transverse (4-lb. wind per square foot on ice-covered conductor) | Conductor | Vertical (conductor plus 32 -in. radial ice) | Transverse (4-lb. wind per square foot on ice-covered conductor) | Conductor loading ${ }^{1}$ |
|  | 2A | 0. 366 | 0. 06799 | 5,876 | 0. 2568 | 0. 2745 | 0. 4258 | 0. 4483 | 0. 2887 | 0. 7232 | 0. 7953 | 0. 4553 | 1. 2065 |
|  | 3A | . 326 | . 05392 | 4,810 | . 2036 | 2445 | . 3682 | . 3872 | . 2753 | . 6615 | . 7172 | . 4420 | 1. 1325 |
|  | 4A | 290 | . 04276 | 3, 938 | . 1615 | . 2175 | . 3209 | . 3294 | . 2633 | . 6118 | . 5427 | . 4300 | 1. 0716 |
|  | 5 A | 258 | . 03391 | 3, 193 | . 1281 | . 1935 | 2821 | . 2860 | 2527 | . 5716 | . 5994 | . 4193 | 1. 0216 |
|  | 6 A | . 230 | . 02689 | 2, 585 | . 1016 | . 1725 | . 2502 | . 2508 | . 2433 | 5395 | . 5555 | . 4100 | . 9804 |
|  | 7A | . 223 | . 02516 | 2, 754 | . 09366 | . 1673 | 2417 | . 2407 | . 2410 | 5306 | . 5432 | . 4077 | 9692 |
|  | 8A. | . 199 | . 01995 | 2, 233 | . 07427 | . 1493 | 2168 | . 2139 | . 2330 | . 5063 | . 5089 | . 3997 | . 9371 |
|  | 1/OF | . 388 | . 09207 | 6,356 | . 3541 | . 2910 | . 5083 | . 5524 | . 2960 | . 8167 | . 9062 | . 4627 | 1. 3075 |
|  | 1 F | . 346 | . 07303 | 5, 266 | . 2809 | 2595 | . 4324 | . 4462 | . 2820 | . 7349 | . 8069 | . 4487 | 1. 2133 |
|  | 2 F | . 308 | . 05792 | 4, 233 | . 2228 | 2310 | . 3709 | . 3963 | 2693 | . 6691 | . 7252 | . 4360 | 1. 1362 |
|  | 4 C | . 284 | . 04098 | 3, 231 | . 1548 | 2130 | 3133 | . 3208 | . 2613 | . 6038 | . 6423 | . 4280 | 1. 0618 |
|  | 6 C | . 255 | . 02577 | 2, 143 | . 0973 | . 1688 | . 2448 | . 2450 | . 2417 | . 5342 | . 5481 | . 4083 | . 9735 |
|  | 8 C | . 179 | . 01604 | 1, 362 | . 06067 | . 1343 | . 1974 | . 1940 | . 2263 | . 4881 | . 4829 | . 3930 | 9126 |
|  | $91 / 2 \mathrm{D}$ | . 174 | . 01539 | 1, 743 | . 05646 | . 1305 | . 1922 | . 1883 | . 2247 | . 4832 | . 4755 | . 3913 | 9059 |
|  | 3 No. 10 | . 220 | . 02446 | 2, 882 | . 08713 | . 1650 | . 2366 | . 2332 | . 2400 | . 5246 | . 5348 | . 4067 | . 9619 |
|  | 3 No. 11 | . 196 | . 01940 | 2, 286 | . 06910 | . 1470 | . 2124 | . 2078 | . 2320 | . 5015 | . 5019 | . 3983 | . 9310 |
|  | 3 No. 12. | . 174 | . 01539 | 2, 040 | . 05480 | . 1305 | . 1915 | . 1866 | . 2247 | . 4821 | . 4739 | . 3913 | . 9046 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

[^30]HORIZONTAL LOAD TO BE GUYED (POUNDS)


1. FIND LOAD TO BE GUYED ON TOP SCALE (ACTUAL LOAD X SAFETY FACTOR)
2. PROCEED VERTICALLY TO LINE FOR SLOPE OF GUY AREA IN WHICH THIS POINT LIES INDICATES THE PROPER SIZE OF GUY
3. FIND TENSION IN GUY WIRE BY FOLLOWING CIRCLE
4. FIND THE VERTICAL COMPONENT OF THE LOAD BY FOLLOWING A HORIZONTAL LINE TO THE SCALE ON THE LEFT

Figure 65. Load held by various guy strands at any slope.

Table 122. Maximum Loads on Single Arms Without Arm Guys

| Cross arm size (inches) | Equivalent maximum allowable horizontal load at end of pin (pounds) | Equivalent maximum allowable unbalaneed borizontal load at end of pin (pormds) | Equivalent maximum allowable vertical load at end of pin (pounds) |
| :---: | :---: | :---: | :---: |
| $38 \times 31 / 4 \times 41 / 4$. | 900 | 600 | 1, 000 |
| $38 \times 31 / 2 \times 41412$ | 1,000 | 600 | 1, 150 |
| $38 \times 33 / 4 \times 43 / 4$ | 1,300 | 600 | 1, 250 |
| $67 \times 31 / 4 \times 41 / 4-$ | 500 | 400 | 800 |
| $67 \times 31 / 2 \times 41 / 2$ | 600 | 400 | 900 |
| $67 \times 33 / 4 \times 43 / 4$ | 700 | 400 | 1, 000 |
| $96 \times 31 / 4 \times 414$. | 400 | 250 | 600 |
| $96 \times 31 / 2 \times 41 / 2-$ | 500 | 250 | 750 |
| $96 \times 33 / 4 \times 43 / 4$. | 600 | 250 | 850 |
| $120 \times 31 / 2 \times 41 / 2$ | 300 | 200 | 550 |
| $120 \times 33 / 4 \times 43 / 4$ | 400 | 200 | 650 |
| $120 \times 4 \times 5$. | 500 | 200 | 750 |

Table 123. Maximum Loads on Double Arms Without Arn Guys

| Cross arm size (inches) | Equivalent maximnm allowable horizontal load at end of pin (pounds) | Equivalent maximum allowable unbalanced horizontal load at end of pin (pounds) | Equivalent maximum allowable vertical load at end of pin (pounds) |
| :---: | :---: | :---: | :---: |
| $38 \times 31 / 4 \times 41 / 4-$ | 3, 600 | 1, 000 | 2, 000 |
| $38 \times 31 / 2 \times 41 / 2-$ | 4, 350 | 1,000 | 2, 300 |
| $38 \times 33 / 4 \times 43 / 4$. | 5,200 | 1,000 | 2, 500 |
| $67 \times 31 / 4 \times 41 / 4$ | 1, 850 | 600 | 1, 600 |
| $67 \times 31 / 2 \times 41 / 2$. | 2, 200 | 600 | 1, 800 |
| $67 \times 33 / 4 \times 43 / 4$ | 2, 650 | 600 | 2,000 |
| $96 \times 31 / 4 \times 41 / 4$. | 1, 250 | 400 | 1, 200 |
| $96 \times 31 / 2 \times 41 / 2$. | 1, 450 | 400 | 1,500 |
| $96 \times 33 / 4 \times 43 / 4$. | 1,750 | 400 | 1, 700 |
| $120 \times 31 / 2 \times 41 / 2$ | 1, 100 | 300 | 1, 100 |
| $120 \times 33 / 4 \times 43 / 4$ | 1,350 | 300 | 1, 300 |
| $120 \times 4 \times 5$ | 1,600 | 300 | 1, 500 |



Figure 66. Equivalent load at end-pin position.

Table 124. Wire Sizes for 120-Voll Single-Phase Circuil

| Load (amperss) | Minitnum wire size (AWO) | Service wire size (AWO) | Wire size (AWO) |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Distance one way from supply to load (feet) |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 250) | 300 | 350 | 400 | 450 | 500 |
| 15-.-n----- | 14 | 10 | 14 | 12 | 10 | 8 | 8 | 6 | 6 | 6 | 4 | 4 | 4 | 2 | 2 |
| 20. | 14 | 10 | 12 | 10 | 8 | 8 | 6 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 2 |
| 25. | 12 | 8 | 10 | 8 | 8 | 6 | 6 | 4 | 4 | 4 | 2 | 2 | 2 | 1 | 1 |
| 30. | 12 | 8 | 10 | 8 | 6 | 6 | 4 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 0 |
| 35. | 12 | 6 | 8 | 6 | 6 | 4 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 0 | $2 / 0$ |
| 40 | 10 | 6 | 8 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 0 | 2/0 | $2 / 0$ |
| 45. | 10 | 6 | 8 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | $2 / 0$ | $3 / 0$ |
| 50 | 10 | 6 | 8 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | $2 / 0$ | $2 / 0$ | $3 / 0$ | 3/0 |
| 55 | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | $2 / 0$ | $2 / 0$ | $3 / 0$ | $3 / 0$ | $4 / 0$ |
| 60. | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | $2 / 0$ | 3/0 | $3 / 0$ | 4/0 | 4/0 |
| 65. | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 1 | 0 | 2/0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 | -- - |
| 70 | 8 | 4 | 6 | 4 | 2 | 2 | 1 | 1 | 0 | $2 / 0$ | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 | ---- |
| 75. | 6 | 4 | 6 | 4 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 | --- | --- |
| 80. | 6 | 4 | 6 | 4 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 |  | -- |
| 85. | 6 | 4 | 4 | 4 | 2 | 1 | 1 | 0 | $2 / 0$ | $3 / 0$ | $3 / 0$ | 4/0 |  |  |  |
| 90. | 6 | 2 | 4 | 2 | 2 | 1 | 0 | 0 | 2/0 | $3 / 0$ | 4/0 | 4/0 |  |  |  |
| 95. | 6 | 2 | 4 | 2 | 2 | 1 | 0 | $2 / 0$ | $2 / 0$ | $3 / 0$ | 4/0 |  |  |  |  |
| 100. | 4 | 2 | 4 | 2 | 2 | 1 | 0 | $2 / 0$ | $2 / 0$ | 3/0 | 4/0 |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 125. Wire Sizes for 220-Volt 3-Phase Circuits

| Load (amperes) | Minimum wire size (AWG) | Service wire size (AWG) | Wire size (AWG) |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Distance one way from supply to load (feet) |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 500 | 600 | 700 | 800 | 900 | 1,000 |
| 15. | 14 | 12 | 14 | 12 | 10 | 8 | 8 | 8 | 6 | 6 | 6 | 4 | 4 | 4 | 2 |
| 20 | 14 | 10 | 12 | 10 | 8 | 8 | 6 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 2 |
| 25. | 12 | 8 | 10 | 8 | 8 | 6 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 2 | 1 |
| 30 | 12 | 8 | 10 | 8 | 6 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 1 | 0 |
| 35 | 12 | 8 | 10 | 8 | 6 | 6 | 4 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 0 |
| 40 | 10 | 6 | 8 | 6 | 6 | 4 | 4 | 4 | 2 | 1 | 1 | 1 | 0 | 0 | $2 / 0$ |
| 45. | 10 | 6 | 8 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 0 | 2/0 | 2/0 |
| 50-.--- | 10 | 6 | 8 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 0 | 2/0 | 2/0 | 3/0 |
| 55 | 8 | 6 | 8 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 2/0 | 2/0 | $3 / 0$ | $3 / 0$ |
| 60------------ | 8 | 6 | 6 | 6 | 4 | 2 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | 3/0 | 3/0 | 4/0 |
| 65. | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 2/0 | 2/0 | 3/0 | $3 / 0$ | $4 / 0$ |
| 70. | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 2/0 | 3/0 | 3/0 | 4/0 | 4/0 |
| 75 | 6 | 4 | 6 | 4 | 2 | 2 | 2 | 1 | 0 | $2 / 0$ | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 | -- - - |
| 80 | 6 | 4 | 6 | 4 | 2 | 2 | 1 | 1 | 0 | 2/0 | 3/0 | $3 / 0$ | 4/0 | 4/0 | ----- |
| 85. | 6 | 4 | 6 | 4 | 2 | 2 | 1 | 0 | 0 | 2/0 | $3 / 0$ | 4/0 | 4/0 |  | ---- |
| 90. | 6 | 4 | 6 | 4 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 |  | -. . - |
| 95. | 6 | 4 | 6 | 4 | 2 | 1 | 1 | 0 | 2/0 | $3 / 0$ | $3 / 0$ | 4/0 | --- |  |  |
| 100 | 4 | 2 | 4 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 | --- |  |  |
| 125. | 4 | 2 | 4 | 2 | 1 | 0 | 2/0 | 2/0 | $3 / 0$ | 4/0 |  |  |  |  |  |
| 150 | 2 | 2 | 2 | 2 | 0 | 2/0 | 2/0 | $3 / 0$ | 4/0 |  |  |  |  |  |  |
| 175 | 2 | 1 | 2 | 1 | 0 | 2/0 | 3/0 | 4/0 | 4/0 | ---- |  |  |  |  |  |
| 200. | 1 | 0 | 1 | 0 | 2/0 | 3/0 | 4/0 | 4/0 | --- |  |  |  |  |  | --- |
| 225. | 0 | 0 | 0 | 0 | 2/0 | 3/0 | 4/0 | --. |  |  |  |  |  |  | ---- |
| 250 | 2/0 | 2/0 | 2/0 | 2/0 | 3/0 | 4/0 | - - . |  |  |  |  |  |  |  | -- - |
| 275 | 3/0 | 3/0 | 3/0 | 3/0 | $3 / 0$ | 4/0 | ---- |  |  | -- | ---- | -- |  |  |  |
| 300 | 3/0 | 3/0 | $3 / 0$ | $3 / 0$ | 4/0 | --- | -- | -- |  |  |  |  |  |  |  |
| 325.---------- | 4/0 | $4 / 0$ | 4/0 | 4/0 |  |  |  |  |  |  |  |  |  |  | ---- |

Table 126. Wire Sizcs for 240-Voll Single-Phase Circuils

| Load (ampores) | Miniunum wiro sizo (AWG) | Service wire size (AWG) | Wire slze (AWG) |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Distance one way from supply to load (feet) |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 500 | 600 | 700 | 800 | 900 | 1,000 |
| 15. | 14 | 10 | 14 | 12 | 10 | 9 | 8 | 6 | 6 | 6 | 4 | 4 | 4 | 2 | 2 |
| 20. | 14 | 10 | 12 | 10 | 8 | 8 | 6 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 2 |
| 25. | 12 | 8 | 10 | 8 | 8 | 6 | 6 | 4 | 4 | 4 | 2 | 2 | 2 | 1 | 1 |
| 30 | 12 | 8 | 10 | 8 | 6 | 6 | 4 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 0 |
| 35. | 12 | 6 | 8 | 6 | 6 | . 4 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 0 | $2 / 0$ |
| 40. | 10 | 6 | 8 | 6 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 0 | 2/0 | $2 / 0$ |
| 45. | 10 | 6 | 8 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | 2/0 | 3/0 |
| 50 | 10 | 6 | 8 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | $2 / 0$ | $2 / 0$ | $3 / 0$ | $3 / 0$ |
| 55. | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 2 | 1 | 0 | 2/0 | $2 / 0$ | $3 / 0$ | $3 / 0$ | 4/0 |
| 60. | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 1 | 1 | 0 | 2/0 | 3/0 | $3 / 0$ | 4/0 | $4 / 0$ |
| 65 | 8 | 4 | 6 | 4 | 4 | 2 | 2 | 1 | 0 | 2/0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 | ---- |
| 70 | 8 | 4 | 6 | 4 | 2 | 2 | 1 | 1 | 0 | 0 | 2/0 | 3/0 | 4/0 | 4/0 | ----- |
| 75 | 6 | 4 | 6 | 4 | 2 | 2 | 1 | 0 | 0 | 2/0 | $3 / 0$ | 4/0 | $4 / 0$ | -- | ---- |
| 80. | 6 | 4 | 6 | 4 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 |  | --- |
| 85 | 6 | 4. | 4 | 4 | 2 | 1 | 1 | 0 | $2 / 0$ | 3/0 | 3/0 | 4/0 | --- |  | --- |
| 90. | 6 | 2 | 4 | 2 | 2 | 1 | 0 | 0 | $2 / 0$ | $3 / 0$ | 4/0 | 4/0 |  |  | ---- |
| 95. | 6 | 2 | 4 | 2 | 2 | 1 | 0 | $2 / 0$ | 2/0 | $3 / 0$ | 4/0 |  |  |  |  |
| 100 | 4 | 2 | 4 | 2 | 2 | 1 | 0 | $2 / 0$ | 2/0 | $3 / 0$ | 4/0 |  |  |  | --- |
| 125 | 4 | 2 | 4 | 2 | 1 | 0 | 2/0 | 3/0 | 3/0 | 4/0 |  |  |  |  |  |
| 150 | 2 | 1 | 2 | 1 | 0 | 2/0 | 3/0 | 4/0 | 4/0 | -- - |  |  |  |  |  |
| 175. | 2 | 0 | 2 | 0 | 2/0 | $3 / 0$ | 4/0 | 4/0 |  |  |  |  |  |  |  |
| 200. | 1 | 0 | 1 | 0 | $2 / 0$ | $3 / 0$ | 4/0 |  |  |  |  |  |  |  | ---- |
| 225 | 1/0 | $2 / 0$ | 1/0 | 2/0 | $3 / 0$ | 4/0 |  |  |  |  |  |  |  |  | ---- |
| 250 | 2/0 | $2 / 0$ | $2 / 0$ | $2 / 0$ | $3 / 0$ | 4/0 |  |  |  |  |  |  |  |  | ---- |
| 275. | $3 / 0$ | 3/0 | 3/0 | $3 / 0$ | 4/0 |  |  |  |  |  |  |  |  |  | ---- |
| 300 | 3/0 | 3/0 | $3 / 0$ | 3/0 | 4/0 |  |  |  |  |  |  |  |  |  | ---- |
| 325--.-...--. | 4/0 | $4 / 0$ | 4/0 | $4 / 0$ |  |  |  |  |  |  |  |  |  |  | $\ldots$ |

Table 127. Incandescent Lamps

| Watts | Volts | Bulb type ${ }^{1}$ | Bulb finish | Base | Rated lifehours | Purpose |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 10 | 120 | S-14 | Inside frost_ | Medium | 1,500 | General. |
| 15 | 120 | A-15 | Inside frost. | Medium | 1, 200 | General. |
| 25 | 120 | A-19 | Inside frost. | Medium | 1,000 | General. |
| 25 | 120 | A-19 | Ruby | Medium | 1,000 | Photography. |
| 25 | 120 | T-10 | Clear | Medium | 1,000 | Showease. |
| 25 | 220 | A-19 | - Inside frost | Medium | 1,000 | General. |
| 40 | 120 | A-19 | Inside frost. | Medium | 1,000 | General. |
| 50 | 120 | A-19 | Rough service_ | Medium- | 1,000 | Automotive, mechanies, etc. |
| 50 | 230 | A-19 | Inside frost. | Medium | 1,000 | General. |
| 60 | 120 | A-19 | Inside frost | Medium. | 1,000 | General. |
| 100 | 120 | A-21 | Inside frost | Medium. | 750 | General. |
| 100 | 220 | A-23 | Inside frost | Medium_ | 750 | General. |
| 150 | 120 | PS-25 | Inside frost | Medium | 750 | General. |
| 200 | 120 | PS-30 | Inside frost | Medium- | 750 | General. |
| 200 | 230 | PS-30 | Inside frost | Medium | 750 | General. |
| 300 | 120 | PS-35 | Inside frost.-_ | Medium- | 750 | General. |
| 300 | 120 | PS-35 | Inside frost. | Mogul - | 1,000 | General. |
| 500 | 120 | PS-40 | Inside frost. | Mogul.- | 1,000 | General. |
| 500 | 230 | PS-40 | Inside frost | Mogul_- | 1,000 | General. |
| 750 | 120 | PS-52 | Inside frost | Mogul. - | 1, 000 | General. |
| 1,000 | 120 | PS-52 | Inside frost.- | Mogul - | 1,000 | General. |
| 1,500_. | 120 | PS-52 | Inside frost-- | Mogul - | 1,000 | General. |

I Stocked in theaters of operations.

## 130. Lighting in Theater-of-Operations Construction

Where facilities permit, the following wattages are suggested for lighting in theater-of-operations buildings.

Watts per square foot of floor area



Recreation, bathhouses, kitehens, general work spaces, noncritical_--.-- . 50

Offices, laundry, shops-low mounting heights up to 10 feet (repair or production)

1. 00

## 131. Miscellaneous Electrical Data

a. Number of Insulated Wires Allowed in Various Sized Conduits. See table 128.
b. Number of conductors in a box.
(1) Table 129 gives the maximum number of conductors, not counting fixture wires, permitted in outlet and junction
boxes. This table applies where no fittings or devices, sucb as fixture studs, cable clamps, hickeys, switches, or receptacles are contained in the box. Where one or more fixture studs, cable clamps, or hickeys are contained in the bor, the number of conductors shall be one less than shown in the tables, with a further deduction of one conductor for one or several flush devices mounted on the same strap. A conductor running through the box is counted as one conductor and each conductor originating outside the box and terminating inside the box is counted as one conductor. Conductors of which no part leaves the box are not to be counted in the above computation. If single flush boxes are ganged, and each section is occupied by a flush device or combination of flush devices on the same strap, the limitations will apply to each section individually.
(2) Table 130 applies for combinations not shown in table 129.
c. Full-load Current and Circuit-breaker Sizes for Alternating-current Motors. See table 130.

Table 128. Number of Insulated Wires Allowed in Various Sized Conduits

| Size AWG MCM | 1 | Number of conductors in one conduit or tubing |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 18. | 1/2 | 1/2 | 1/2 | 3/2 | 1/2 | 1/2 | 1/2 | $3 / 4$ | $3 / 4$ |
| 16. | 1/2 | 1/2 | 3/2 | 1/2 | 1/2 | 3/2 | 3/4 | $3 / 4$ | 3/4 |
| 14 | 3/2 | 1/2 | 1/2 | 1/2 | $3 / 4$ | 3/4 | 1 | 1 | 1 |
| 12 | 1/2 | 1/2 | 3/2 | $3 / 4$ | $3 / 4$ | 1 | 1 | 1 | 13/4 |
| 10 | 1/2 | $3 / 4$ | 3/4 | 3/4 | 1 | 1 | , | 11/4 | 11/4 |
| 8. | 1/2 | $3 / 4$ | $3 / 4$ | 1 | 11/4 | 11/4 | 11/4 | 11/2 | 11/2 |
|  | 1/2 | 1 | 1 | 11/4 | 11/2 | 11/2 | 2 | 2 | 2 |
| 4 | 1/2 | 114/4 | 11/4 | 11/2 | 11/2 | 2 | 2 | 2 | 21/2 |
|  | $3 / 4$ | 11/4 | 11/4 | 11/2 | 2 | 2 | 2 | 21/2 | 21/2 |
| 2--.--------- | $3 / 4$ | 174 | 11/4 | 2 | 2 | 2 | 21/2 | 21/2 | $21 / 2$ |
| 1 | $3 / 4$ | 11/2 | 11/2 | 2 | $21 / 2$ | 21/2 | $21 / 2$ | 3 | 3 |
| 0 | 1 | 1 112 | 2 | 2 | 21/2 | 21/2 | 3 | 3 | 3 |
| 00 | 1 | 2 | 2 | 21/2 | 21/2 | 3 | 3 | 3 | 31/2 |
| 000 | 1 | 2 | 2 | 21/2 | 3 | 3 | 3 | $31 / 2$ | 31/2 |
| 0000 | 11/4 | 2 | $21 / 2$ | 3 | 3 | 3 | $31 / 2$ | $31 / 2$ | 4 |
| 250 | 11/4 | $21 / 2$ | 21/2 | 3 | 3 | $31 / 2$ | 4 | 4 | 5 |
| 300. | 11/4 | $21 / 2$ | $21 / 2$ |  | $31 / 2$ | 4 | 4 | 5 | 5 |
| 350 | 1/4/4 | 3 | 3 | $31 / 2$ | $31 / 2$ | 4 | 5 | 5 | 5 |
| 400 | 11/2 | 3 | 3 | $31 / 2$ | 4 | 4 | 5 | 5 | 5 |
| 500. | 11/2 | 3 | 3 | 31/2 | 4 | 5 | 5 | 5 | 6 |

Table 129. Number of Conductors Allowed in Boxes of Certain Sizes

| Box dimensions-Trade stze |
| :--- |

Where there is not sufficient space for a deeper box, four No. 14 AWG conductors may enter a box provided with cable clamps and containing one or more devices on a single mounting strap.

Shallow Boxes of Less Than $11 / 2^{\prime \prime}$ Depth

| Box dimensions-Trade size | Maximum number of conductors |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | No. 14 | No. 12 | No. 10 |  |
| $31 / 4$ | 4 | 4 |  | 3 |
| 4. | 6 | 6 |  | 4 |
| $4^{11 / 16}$ | 8 | 6 |  | 6 |

Table 180. Number of Conductors Allowed in Boxes, Other Combinations

| Size of conductor | Frec space within box for ench conductor |
| :---: | :---: |
| No. 14 | 2 cubic inches. |
| No. 12 | 2.25 cubic inches. |
| No. 10. | 2.5 cubic inches. |
| No. 8. | 3 cubic inches. |

Table 191. Full-Load Current and Circuit-Breaker Sizes for Alternating-Current Motors

| Motorhorsepower | Stagle phase |  |  |  | Three phase |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 110 volt |  | 220 volt |  | 220 volt |  | 440 volt |  |
|  | $\begin{aligned} & \text { Current } \\ & \text { (amps) } \end{aligned}$ | Circuit breaker (amps) | $\begin{gathered} \text { Current } \\ \text { (amps) } \end{gathered}$ | Circuitbreaker (amps) | $\underset{\text { (amps) }}{\text { Current }}$ | Circuitbreaker (amps) | $\underset{\text { (amps) }}{\text { Current }}$ | Circuitbreaker slze (amps) |
| 1/6 | 3. 34 | 15 | 1. 67 | 15 |  |  |  |  |
| 1/4 | 4. 8 | 15 | 2. 4 | 15 |  | -- |  |  |
| 32 | 7 | 15 | 3. 5 | 15 | 2.5 | 15 | 1. 3 | 15 |
| $3 / 4$ | 9. 4 | 25 | 4. 7 | 15 | 2. 8 | 15 | 1. 4 | 15 |
| 1. | 11 | 25 | 5. 5 | 15 | 3. 3 | 15 | 1. 7 | 15 |
| $11 / 2$ | 15. 2 | 35 | 7. 6 | 25 | 4. 7 | 15 | 2. 4 | 15 |
| 2 | 20 | 50 | 10 | 25 | 6 | 15 | 3 | 15 |
| 3 | 28 | 50 | 14 | 35 | 9 | 25 | 4.5 | 15 |
| 5. | 46 | 70 | 23 | 50 | 15 | 35 | 7.5 | 15 |
| 71/2 | 68 | 125 | 34 | 70 | 22 | 50 | 11 | 25 |
| 10 | 86 | 200 | 43 | 70 | 27 | 50 | 14 | 35 |
| 15. |  |  |  |  | 38 | 70 | 19 | 50 |
| 20. |  |  |  |  | 52 | 125 | 26 | 70 |
| 25. |  |  |  |  | 64 | 125 | 32 | 70 |
| 30. |  |  |  |  | 77 | 125 | 39 | 70 |
| 40. |  |  |  |  | 101 | 200 | 51 | 125 |
| 50 |  |  |  |  | 125 | 200 | 63 | 125 |
| 60 |  |  |  |  | 149 | 225 | 75 | 125 |
| 75 |  |  | - |  | 180 | 400 | 90 | 200 |
| 100 |  |  |  |  | 246 | 400 | 123 | 200 |
|  |  |  |  |  |  |  |  |  |

## Section V. SPECIAL UTILITIES

## 132. Refrigerated Warehouses

a. General. Table 132 gives basic data on T/O refrigerated warehouises. For further details see TM 5-302.
b. Types and Capacities. For preliminary planning in areas where refrigerated storage is needed primarily for frozen meat, a storage capacity of 0.02 cubic feet per man per day is satisfactory. For storing all components of the field ration, at least three compartments are needed; one for frozen meat because of the low temperature required, one for butter and shelled eggs because they are contaminated easily by other foods, and one for smoked meats, fruits, and vegetables. The controls are normally operated to maintain temperatures of $10^{\circ} \mathrm{F}$. for frozen meat and $34^{\circ} \mathrm{F}$. for other foods.
c. Illustrative Situations.
(1) Problem. To select refrigerated warehouse capacity suitable for 30 -day storage of rations for $20,000 \mathrm{men}$.
(2) Solution. This is equivalent to 60-day storage for 10,000 men. Table 132 shows that the following are adequate-

|  | $\begin{aligned} & \text { Rations (men } \\ & \text { far } 60 \text { days) } \end{aligned}$ |
| :---: | :---: |
| For frozen beef, 2 warchouses $20^{\prime} \times 100^{\prime}$ | 11,880 |
| For butter and shelled eggs, 1 warehouse $20^{\prime} \times 100^{\prime}$ | 10,560 |
| All other items: |  |
| 4 warehouses $20^{\prime} \times 100^{\prime}$ | 9,520 |
| 1 warehouse $20^{\prime} \times 55^{\prime}$ | 1, 080 |

Table 132. Sizes and Capacities of T/O Refrigerated Warehouses, Standard Frame

| Nominal size | $20^{\prime} \times 55^{\prime}$ | $20^{\prime} \times 100^{\prime}$ | $80^{\prime} \times 220$ |
| :---: | :---: | :---: | :---: |
| Inside dimensions (feet) | $18^{\prime} \times 40^{\prime}$ | $18^{\prime} \times 88^{\prime}$ | ${ }^{77.5^{\prime} \times 197}{ }^{\prime}$ |
| Gross floor area (square fect).- | 720 | 1,584 | 15,267 |
| Ceiling height (feet) | 8 | 8 | 14.5 |
| Height of stack (feet) | 6 | 6 | 12 |
| Equipment. | 2 compressors <br> (20,000 <br> B.t.u. per hour). <br> 1 evap condenser. <br> 1 cooling tower_ <br> 2 unit coolers - | 2 compressors <br> (40,000 <br> B.t.u. per hour). <br> 1 evap condenser. <br> 1 cooling tower. <br> 4 unit coolers . | 1 compressor (78,000 B.t.u. per hour). <br> 2 compressors (180,000 B.t.u. per hour). <br> 1 evap condenser. <br> 1 receiver. 20 unit coolers. |
| Storage capacity |  |  |  |
| Frozen packaged boned bcef: |  |  |  |
| Total pounds.-------- | 81,000 | 178,200. |  |
| Total rations | 162,000 | 356,400. |  |
| Men for 60 days | 2,700. | 5,940......- |  |
| Butter and shelled eggs: |  |  |  |
| Total pounds, butter | 36,000 | 79,200_----- |  |
| Total pounds, eggs | 36,000 | 79,200------ |  |
| Total combined rations. | 288,000 | 633,600-.--- |  |
| Men for 60 days | 4,800 | 10,560. . - - - |  |
| Ham, bacon, bologna, potatoes, onions, and citrus fruits. ${ }^{1}$ |  |  |  |
| Total pounds, ham, bacon and bologna. | 10,200 $\ldots$. $-\ldots$ | 22,440..... |  |
| Total pounds, other items_ | 45,500. | 100,030.----- |  |
| Total combined rations... | 65,000 | 142,900.-.-- |  |
| Men for 60 days-------- | 1,080.------ | 2,380------ |  |

[^31]Table 139. Refrigerant Properlies

|  | Ammonia $\left(\mathrm{NH}_{3}\right)$ | Freon ( $\mathrm{F}-12)\left(\mathrm{CCl}_{2} \mathrm{~F}_{2}\right)$ | Freoll ( $\mathrm{F}-22$ ) $\mathrm{CHHClF}_{2}$ | Methyl cliloride ( $\mathrm{CH}_{3} \mathrm{Cl}$ ) |
| :---: | :---: | :---: | :---: | :---: |
| Critical temperature_- | $271^{\circ} \mathrm{F}$ | $233^{\circ} \mathrm{F}$ | $204.8{ }^{\circ} \mathrm{F}$ | $290^{\circ} \mathrm{F}$. |
| Flammability------- | Burns if heated. May cxplode under certain conditions. | Nonflammable and nonexplosive. | Nonflammable and nonexplosive. | Flammable but docs not burn readily. Explosive under certain conditions. |
| Effect on metals...-.- | Reacts with copper and brass if water vapor is present. Slight effect on iron and stecl. | Noncorrosive | Noncorrosive_ | Noncorrosive. |
| Effect on lubricants -- | No effect if ammonia is anhydrous. If moisture is present, tends to form emulsion. | No effcct. Mixes with oil in all proportions. | No cffcct. Mixus with oil in all proportions. | Dissolves all kinds of oil. Glycerine and white mincral oils must be used. |
| Effect on personnel... | Injurious if exposure is prolonged and gas concentration is above $1 / 30$ of 1 percent. Very irritating to eyes and nose. | Practically nontoxic. | Practically montoxic. | Concentration of 2 pereent to $21 / 2$ percent for 2 hours may cause death. |
| Tests for leaks_ | By smoll. Exact location found with sulfur candles. ${ }^{1}$ | (2)---- | (2) --- | Smells like chloroform. Alcohol flame in methyl chloride has greenish tinge. |

[^32]
## 134. Iceplant Characteristics

Table 134. Iceplants

|  | 1-ton | 3.6-ton | 15-ton |
| :---: | :---: | :---: | :---: |
|  | 66-5710.01-0 | 66-5710.06-0 | 66-5710. 15-0 |
| Weight (pounds crated for export) Cubage (cubic feet crated for export) Connected electrical load----------- | 10, 200 | 27, 500 | 120,600 |
|  | 427 | 1,314 | 4, 950 |
|  | None | $\begin{aligned} & 12.24 \\ & \mathrm{kv.}-\mathrm{a} . \end{aligned}$ | 57. 76 |
|  |  | $\begin{aligned} & 11.40 \\ & \text { kv.-a. } \end{aligned}$ | 55. 26 |

## 135. Air Conditioning

a. Authorized Uses. In tropical climates air conditioning is used in hospitals or installations to protect patients or mechanical equipment from excess heat and humidity. Its usc is not authorized to provide comfort for personnel in normal health even though it might incrcase efficiency. Air conditioning is used in all climates for certain photographic reproduction processes and for the repair and adjustment of instruments; for example, some types of radar and bombsight equipment require controlled tempcrature and humidity.
b. Standard Unit. The standard Army air-conditioning unit developed for use in theater-of-operations construction is self-contained, water-cooled, and powercd by a 5 -horsepower motor. It has a capacity of 70,000 British thermal units per hour. In tropical temperatures, one unit will air-condition a space 20 by 20 fect (or equivalent) with 100 percent fresh-cooled air, or a space 20 by 40 feet (or equivalent) with 33 percent fresh air and 67 percent rcconditioned air. The unit consists of an air-handling cabinet 8 feet high 4 feet wide, and 1 foot 8 inches deep and a cooling tower 8 feet high, 4 fcct wide, and 2 fcet 6 inches deep. Thc shipping weight and cubage of both items are 3,745 pounds and 206 cubic feet.

## 136. Boilers and Accessories

a. Types and Rating.

| Type | Rating (boiler horsepower) |
| :---: | :---: |
| Vertical steel fire tube | $\left\{\begin{array}{l}15 \\ 25\end{array}\right.$ |
|  | ( $\begin{array}{r}35 \\ 60\end{array}$ |
| Horizontal steel fire tube. | 200 |
| Portable steel firebox. - | 143 |

## b. Other data.

Table 135. Data on Boiler Feed Pumps

| Size | $3 \times 2 \times 3$ | $41 / 2 \times 3 \times 4$ | $514 \times 332 \times 5$ |
| :---: | :---: | :---: | :---: |
| Minimum capacity of pump, (gallons per minute) $\qquad$ | 6 | 10 | 25 |
| Maximum piston speed (feet per minute)-- | 14 | 20 | 25 |
| Size of steam inlet (inches) | $3 / 4$ | 3/4 | 3/4 |
| Size of exhaust outlet (inches) | $3 / 4$ | 2 | 2 |
| Size of water suction (inches) | 2 | 2 | 2 |
| Size of water discharge (inches) | $3 / 4$ | $3 / 4$ | 2 |
| Weight, crated for export (pounds)-.......- | 350 | 400 | 600 |
| Cubage, crated for export (cubic feet)------ | 5 | 7 | 10 |

Table 136. Data on Feed-Water Heaters

| Coil surface (sq. ft.) minimum | 20 | 30 | 75 |
| :---: | :---: | :---: | :---: |
| Condensing capacity (pounds per hour) | 100 | 160 | 400 |
| Water flow (gallons per minute) minimum . | 6 | 10 | 25 |
| Steam-supply connection (inches) | 3/4 | 2 | 2 |
| Condensate connection (inches) | 3/4 | $3 / 4$ | 3/4 |
| Water inlet and outlet (inches) | $3 / 4$ | $3 / 4$ | 22 |
| Safety valve (inches). | $3 / 4$ | 3/4 | 11/2 |
| Connections to oil separator (inches) | 3/4 | $3 / 4$ | 2 |
| Grease trap, inlet and outlet (inches) .-....- | 3/4 | $3 / 4$ | 3/4 |
| Float and thermostatic trap inlet and outlet (inches) | 3/4 | $3 / 4$ | 3/4 |
| Weight, crated for export (pounds) | 225 | 250 | 325 |
| Cubage, crated for export (cubic feet) | 9 | 11 | 13 |

Table 137. Data on Surge Tanks

| Capacity (gal) | 72 | 145 | 185 |
| :---: | :---: | :---: | :---: |
| Tank dimensions | 24 by 42 | 24 by 72 | 30 by 60 |
| Installed position | Horizontal | Horizontal | Vertical |
| Condensate return connection (inches) -- | 2 | - 2 | 2 |
| Feed-water connection (inches) | 3/4 | 3/4 | $3 / 4$ |
| Vent connection (inches) | 2 | 2 | 2 |
| Pump suction connection (inches) | 2 | 2 | 2 |
| Drain connection (inches) | 3/4 |  | 3/4 |
| Weight, crated for export (pounds) | 560 | 800 | 900 |
| Cubage, crated for export (cubic feet)---- | 18 | 25 | 30 |

Table 188. Data on Storage Type Hot-Water Generators

| Storage capacity (gal) | 750 | 365 | 220 |
| :---: | :---: | :---: | :---: |
| Diameter of shell (inches) | 48 | 36 | 30 |
| Length of shell (inches) | 96 | 84 | 72 |
| Shell thickness (inches) minimum-.-- | 0. 312 | 0. 250 | 0. 187 |
| Coil heating surface (squíare feet) minimum. | 33 | 10 | 5 |
| Tappings for hot- and cold-water connections (inches) | ${ }^{1} 4$ | 2 | 2 |
| Tappings for steam, condensate, rclicf, and drain connections (inclies)-- | 2 | 2 | 2 |
| Combination temperature and pres-sure-relief valve (capacity in British thermal units). $\qquad$ | 1,000, 000 | 300, 000 | 300, 000 |
| Sizc of temperature regulating valve (inches) | 11/2 | 1 | $3 / 4$ |
| Weight, crated for export (pounds) - - | 2, 250 | 1,700 | 1,200 |
| Cubage, crated for export (cubic feet) - | 112 | 86 | 60 |

${ }^{1}$ Four-ineh connections are flanged with threaded east-iron companion flanges and necessary nuts, bolts, and gaskets.

Table 199. Data on Boilers

| Stock No. | Item |
| :---: | :---: |
| $4410-277-3139$ | Boiler, steam, high pressure, horizontal; horsepower not rated, <br> 400 lb. stcam; forced or induced draft, oil fired. <br> Boiler, steam, high prcssure, horizontal; 200 hp., 6,900 lb. steam; <br> forced draft; oil fired, w/27 accessories. <br> Boiler, steam, high pressure, vertical; 60 hp., steam dclivery not <br> rated; induced draft, coal fired, hand, or oil fired. |

## 137. Steam Generators

Table 140. Steam Generators

| Rating pounds of steam per hour | 400 | 200 |
| :---: | :---: | :---: |
| Weight, crated for export (pounds) | 4, 000 | 3, 000 |
| Cubage, crated for export (cubic feet) | 160 | 120 |
| Condensate pump (gallons per minute) | 3 | $11 / 2$ |
| Condensate receiver, capacity (gallons) | 10 | 10 |
| Oil burner (gallons per hour at rated capac | 4 | 2 |
| Connections (inches): |  |  |
| Condensate return | 3/4 | $3 / 4$ |
| Make-up water | $3 / 4$ | $3 / 4$ |
| Blowoff (blowdown) | 3/4 | 3/4 |
| Steam supply | 2 | 2 |
| Motor, fan (horsepower) | $3 / 4$ | 3/4 |
| Motor, condensate pump (horsepower) -- | 3/4 | 3/4 |

138. Utilities Requirements of Mess Buildings

|  | Troop | Hospital |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{gathered} \text { Patients } \\ \substack{\text { (1,000-and } \\ 7500-\mathrm{bed})} \end{gathered}$ | Patients (500and 250 -bcd) | (100 s-ljed) | $\begin{aligned} & \text { Detachment } \\ & \text { (1,000- and } \\ & 750 \text {-bed) } \end{aligned}$ | Detachment (500-bed) | Oflicers and nurses (1,000and 750 -bed) | Officers and nurses |  |
|  |  |  |  |  |  |  |  | (250-bed) | (500-Jed) |
| Size: |  |  |  |  |  |  |  |  |  |
| Seating capacity_ | 120 | 256 | 224 | 112 | 224 | 176 | 168 | 56 | 96 |
| Feeding capacity | 170 | 300 | 300 | 280 | 300 | 280 | 280 | 112 | 170 |
| Kitchen feeding (maximum) capacity | ${ }^{9} 170$ | 1,000 | 500 | 280 | 500 | 280 | 280 | 170 | 170 |
| TO number, TM 5-280_- | 11. 10 A | 35. 17 | 35. 17 | 35. 17 | 35. 17 | 35. 17 | 35. 17 |  |  |
|  |  | sheet 1 | sheet 2 | sheet 3 | sheet 4 | sheet 5 | sheet 6 |  |  |
| Climate---------------- | Temp | 'Iemp | Temp | Temp | 'Temp | Temp | Temp |  |  |
| Equipment: |  |  |  |  |  |  |  |  |  |
| Range, cooking-------- | 2 | 10 | 5 | 3 | 5 | 3 | 3 |  |  |
| Bain marie, $72^{\prime \prime}$ by $36^{\prime \prime}$ - |  | 1 |  |  |  |  | 1 |  | --- |
| Water heater, 50-gal. per hour ( $58^{\circ} \mathrm{F}$. rise) - | 1 |  |  |  |  |  |  |  |  |
| Range boiler, 82-gal - -- $^{\text {- }}$ | 1 |  |  |  |  |  | --------- |  |  |
| Hot-water generator, 10 sq. ft., 330-gal. |  | 1 |  | 1 | 1 | 1 | 1 |  |  |
|  |  |  |  |  |  |  |  |  |  |
| Refrigerator, US No. 20_ |  |  |  | 1 |  |  |  |  |  |
| $45^{2}$ |  | 1 | 1 |  | 1 | 1 | 1 |  |  |
| Dishwasher, 180-DA |  | 1 | 1 | ----- |  |  |  |  |  |
| Dishwasher, 50-SM.. |  |  |  | ${ }^{3} 1$ |  |  | ${ }^{3} 1$ |  |  |

Steam generator ${ }^{4}$ (selfcontained) $200-\mathrm{lb}$. per hour $\qquad$
Steam generator ${ }^{4}$ (self-
contained) $400-\mathrm{lb}$.
per hour Power:

Basic plan ${ }^{1}$ (with dishwasher)
2 Light
Power_-.-----
Total kilovoltamperes.
Alternate plan ${ }^{1}$ (without dishwasher)
Light
Power Total kilovolt amperes.
ption
Water consumpti
(estimated) :
Gallons per day (maximum) with hand washer (alternate plan) $\qquad$
Gallons per day (maximum) with machine washing (basic plan)-------------
15,000

1 Sec TM 5-302 for layout and drawlags.
${ }^{2}$ Replaced with US 65 refrigerator.
${ }^{3}$ Same as type $\mathrm{A}, 2,000$-plate dishwasher.
${ }^{4}$ Sce par. 137.
${ }^{5}$ No basie plan.
${ }^{0}$ No alternate plan.
${ }^{1}$ Based on 6 gal. per person per day with hand dishwashing and 5 gal. per person per day with machine dishwashing.
${ }^{8}$ For patients, detachment, offieers, and nurses.

- Capacity based on use of heavy-duty ranges.


# CHAPTER 9 STRUCTURAL DESIGN DATA 

## Section I. DESIGN LOADS

## 139. General

This chapter provides data for the design or classification of nonstandard fixed bridges, buildings, and similar structures required for temporary use in theaters of operation, based on the use of standard or commercial construction materials. The data for wind loads and impact loads on bridges has been simplified so as to eliminate many factors normally considered in bridge design. For bridge structures of a more permanent type, refer to the latest editions of The American Association of State Highway Officials, Standard Specifications for Highway Bridges, and American Railway Engineering Association Specifications. For designs based on materials differing from those in general use in the United States, modifications in values of working stresses may be required. Safe loads for standard and prefabricated bridges and buildings are given elsewhere in this text or in appropriate technical manuals. In general, information on structural design of the various materials is simplified and elementary, and does not point out all the details to be considered in making designs. It is intended to be used under the guidance of persons with enough experience in design to recognize this.

## 140. Dead Loads

a. General. The weights of the elements of a structure are computed and combined as required for the design of each structural member. Utilities, such as water tanks, which are an integral part of a structure are included in dead loads. Structural members are designed using assumed values for their own weights, then redesigned if necessary.
b. Highway Bridge Floor and Stringers. Tables 142, 143, and 144 give dead load in pounds per linear foot of bridge, for three types of bridge.
c. Wood-Roof Trusses. Preliminary allowances for the weight of wood-roof trusses, in pounds per square foot of horizontal projection of the area supported, are:
(1) Pitched trusses, $0.064 L$.
(2) Flat-top Pratt trusses, $0.043 L \div 1.75$.
(3) Bowstring trusses, $0.038 L \div 0.60$.

Where $L=$ span of truss in feet.

Table 142. Dead Load in Pounds Per F'pot of Bridge-6-Ineh Timber Floor wilh Timber Stringers, Curb, and Railing

| Class | T'ype | Span in feet |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|  | Single-lane 14'-roadway - | 400 | 410 | 410 | 420 | 420 | 430 | 430 | 440 | 440 | 450 | 450 | 460 | 460 |
|  | Double-lane 24'-roadway _ | 640 | 650 | 660 | 670 | 680 | 690 | 690 | 700 | 710 | 720 | 730 | 740 | 740 |
| 24------ | Single-lane 14'-roadway- - | 460 | 470 | 480 | 490 | 500 | 510 | 510 | 520 | 530 | 540 | 550 | 560 | 560 |
|  | Double-lane 24'-roadway | 730 | 750 | 770 | 790 | 810 | 820 | 840 | 860 | 880 | 900 | 920 | 930 | 950 |
| 70. | Single-lane 14'-roadway - | 500 | $5: 30$ | 560 | 580 | 610 | 640 | 660 | 690 | 720 | 740 | 770 | 800 | 820 |
|  | Double-lane 24'-roadway | 840 | 880 | 930 | 970 | 1, 020 | 1, 050 | 1,090 | 1, 130 | 1, 170 | 1, 220 | 1,260 | 1,300 | 1,340 |

Table 148. Dead Load in Pounds Per Foot of Bridgc—Steel Stringers with 6-1neh Timber Floor—Timber Curb, and Railing

| Cluss | Type | Spatu in feet |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 20 | 30 | 40 | 50 | (i) | 70 | so | 90 | 100 |
| 8------- | Single-lane 14'-roadway | 480 | 520 | 560 | 600 | 630 | 670 | 710 | 750 | 780 |
|  | Double-lane $24^{\prime}$-roadway | 770 | 840 | 900 | 970 | 1, 030 | 1, 100 | 1, 160 | 1, 220 | 1,280 |
| 24.- | Single-linc 14'-roadway $-\ldots-\ldots$ | 570 | 620 | 660 | 710 | 750 | 800 | 840 | 890 | 930 |
|  | Double-lane 24'-roadway-....-- | 940 | 1, 010 | 1, 080 | 1, 150 | 1, 220 | 1,290 | 1, 360 | 1, 430 | 1,500 |
|  | Single-lane 14'-roadway-------- | 650 | - 740 | 830 | 920 | 1, 010 | 1, 100 | 1,190 | 1,280 | 1, 370 |
|  | Double-lane 24'-roadway . . . . . - | 1, 050 | 1, 210 | 1, 370 | 1, 530 | 1,690 | 1, 850 | 2, 010 | 2, 170 | 2,320 |

Table 144. Dead Load in Pounds Per Fool of Bridge—Steel Stringers with 6-Inch Concrete Floor and Concrete Curb-Timber Railing

| Class | Type | Span in feet |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 8.-...-- | Single-lane 14'-roadway | 1,500 | 1,560 | 1, 610 | 1, 670 | 1,720 | 1, 780 | 1,830 | 1,880 | 1,930 |
|  | Double-lane $24^{\prime}$-roadway | 2, 250 | 2,330 | 2, 400 | 2, 480 | 2, 550 | 2, 630 | 2, 700 | 2, 780 | 2, 850 |
|  | Single-lane 14'-roadway | 1,580 | 1, 650 | 1, 720 | 1,790 | 1, 860 | 1, 930 | 2, 000 | 2, 070 | 2, 140 |
|  | Double-lane 24'-roadway | 2, 360 | 2, 480 | 2, 590 | 2, 700 | 2, 810 | 2, 920 | 3,030 | 3, 140 | 3,250 |
|  | Single-lane $14^{\prime}$-roadway | 1, 660 | 1, 770 | 1, 880 | 1,980 | 2, 100 | 2, 210 | 2, 320 | 2, 430 | 2, 540 |
|  | Double-lane 24'-roadway ------ | 2, 480 | 2, 680 | 2, 880 | 3, 080 | 3, 270 | 3, 470 | 3,670 | 3, 870 | 4, 060 |

d. Steel-Roof Trusses.

$$
w=\frac{p L}{150+5 L+\frac{p S}{3}}
$$

Where $w=$ weight of truss in pounds per square foot of horizontal projection of the area supportcd.
$p=$ total load in pounds per square foot of horizontal projection of the arca supported.
$L=$ span of truss in feet.
$S=$ spacing of trusses in feet.
e. Weights of Materials. The weights of materials, given for estimating live loads in paragraph 141 and others given in chapter 10, are also useful in estimating dead loads of structures.

## 141. Live Loads

a. Highway Bridges. Each highway bridge is posted to indicate the class of vehicles that can make a normal crossing under the following conditions: Vehicle traveling in designated lane; maximum specd for critical vehicles 25 miles per hour; no sudden stopping or acceleration; vehicles 25 miles per hour; no sudden stopping or acccleration; vehicles spaccd at lcast 30 yards tail to head. The loading applies to each lane for bridges morc than one lane wide. Maximum shears and rcactions normally occur when one vehicle per lane has its rear axle just over the gap side of an abutment or picr; maximum moment occurs when one velicle per lane is near the center of the span. To determine the moment and shcar caused by the design class vehicle, use the char'ts in figure 67 (1) through (7). 'These valucs are for onclane, and should be doubled for two-lane bridges. Also, duc to the non-uniform lateral distribution of loads through the axles or tracks of military vchicles, a lateral distribution factor of 1.5 is applied to live and impact loads in designing bridge members for moment, shear, and bearing. Allowable deflection for military highway bridge is $1 / 215$ of the span.
b. Railroad Bridges. Cooper's E-45 loading (fig. 68) is used in design. The moments, shears, and pier reactions produced by this loading, for each rail, are tabulated in paragraph 148. The table also gives equivalent uniform loads, per rail, for each span length.
c. Floor Loads for Buildings.
(1) Uniformly distributed loads.
(2) Weights of materials. Assuming normal aisles and working spaces, the weights of various materials which are used in estimating warehousc live loads are shown in table 146.


Figure 67(1). Standard class curves (moment) $0^{\prime}-20^{\prime}$ spans.


Figure 67(2). Standard class curves (moment) 20'-60' spans.


Figure 67(3). Standard class curves (moment) 60'-260' spans.


Figure 67(4). Standard class curves (shear) $0^{\prime}-55^{\prime}$ spans.


Figure $67(5) . \quad$ Standard class curves (shear) 55'-280' spans.


Figure $67(6)$. Dual class curves (moment) $0^{\prime}-30^{\prime}$ spans.


Figure 67(7). Dual class curves (moment) $30^{\prime}-100^{\prime}$ spans.
con

Figure 68. Bridge live load equivalents.

| Use or occupancy | Lice load in pounds 'per square foot |
| :---: | :---: |
| Barracks and small mess and assembly buildings | 40 |
| Offices | - 50 |
| Hospital operating rooms | 60 |
| Mess and assembly rooms with fixed seats | 60 |
| Other assembly rooms and gymnasiums. | 100 |
| Garages, passenger cars only | 75 |
| Garages, trucks, less than 3 tons including load | 100 |
| Garages, trucks, 3 to 10 tons including load | 150 |
| Garages, trucks, over 10 tons including load | 200 |
| Warehouses, light storage | 125 |
| Warehouses, heavy storage | ${ }^{2} 250$ |

1 If special eonditions of use are indicated, the necessity for using heavier values will be investigated.
2 Minimum for any type of materials-handing equipment. Increase as required for heary-dinty materialshanding equipment and for high stocking of materials.
(3) Concentrated loads. For office floors, provision is made for a load of 2,000 pounds placed on any space $21 / 2$ feet square wherever this load upon an otherwise unloaded floor produces stresses greater than those caused by a uniformly distributed load of 50 pounds per square foot. In designing floors in buildings for other purposes, the actual live load caused by the use to which the building is to be put is used in the design of the building or part thereof, and special provision is made for machine or apparatus loads when these result in a greaterload than is given in (1) above.
(4) Partition loads. In buildings designed for live loads less than 100 pounds per square foot, an assumed partition load of 300 pounds per linear foot of masonry partition, or the actual computed partition load, if greater, is used in the design. For permanent or semipermanent buildings not initially divided by partitions, allowance is made in live loads on this basis for future partitions.

## d. Live-Load Reductions.

(1) No live-load reductions are made in roof members nor in buildings used for assembly purposes. In other buildings designed for live loads of 100 pounds or less per square foot, the design live load on any member carrying 150 square feet or more may be reduced at the rate of 0.08 percent per square foot of area supported by the member. The reduction shall not exceed 60 percent nor shall it exceed $100 \times \frac{D+L}{4.33 L}$ where $D$ is dead load and $L$ is live load, both in pounds per square foot of area supported by the member.

Table 146. Material Weights

| Material 1 | Weight of material per cu ft of space (pounds) | $\underset{\text { (feet) }}{\text { Height of pile }}$ | Weight per sq ft of floor (pounds) | Recommended live load (pounds per square foot) |
| :---: | :---: | :---: | :---: | :---: |
| Building materials: |  |  |  |  |
| Bricks | 45 | 6 | 270 | 300 |
| Portland cement | 72 to 105 | 6 | 432 to 630 | to |
| Lumber | 45 | 6 | 270 | 400 |
| Painting materials: |  |  |  |  |
| Linseed oil in drums .-. - | 45 | 4 | 180 | 200 to 300 |
| White lead paste in cans.- | 174 | $31 / 2$ | 610 |  |
| Dry goods: |  |  |  |  |
| Cotton sheeting, in cases.- | 23 | 8 | 184 | 200 to |
| Wool, in bales, compressed | 48 |  |  | 250 |
| Groceries: |  |  |  |  |
| Canned goods in cases_.-- | 58 | 6 | 348 | 250 |
| Coffee, roasted, in bags--- | 33 | 8 | 264 | to |
| Sugar, in cases--------- | 51 | 6 | 306 | 300 |
| Hardware: |  |  |  |  |
| Chain---------------- | 100 | 6 | 600 | 300 |
| Wire, insulated copper, in coils $\qquad$ | 63 | 5 | 315 | to |
| Wire, galvanized iron, in coils. | 74 | 41/2 | 333 | 400 |
| Miscellaneous: |  |  |  |  |
| Tires------------------ | 30 | 6 | 180 |  |
| Books (solidly packed) .-- | 65 | 6 | 390 | ----------- |
| Paper (newspapers)------ | 35 | 6 | 210 | ----------- |
| Rope, in coils.-.....-.-- | 32 | 6 | 192 | ------------ |
| Rubber, crude.--------- | 50 | 8 | 400 | ----------- |
| Chinaware, in crates...-- | 40 | 8 | 320 | ----------- |

1 See par. 219 also. (Reprinted from "Steel Construction" by permission of American Institute of Steel Construction, copyright 1947.)
(2) In buildings designed for live loads of more than 100 pounds per square foot, no reductions are made except that live loads on columns may be reduced 20 percent.

## 142. Roof Live Loads

For buildings in locations with climates similar to those of the three zones into which the United States has been divided for this purpose, roof live loads in pounds per square foot of horizontal projection are given in figure 69.


Figure 69. Roof live loads in the United States.

## 143. Wind Loads

a. Bridges. Short bridges are designed with no allowance for wind. For bridges of 100 -foot span or more, the following wind loads are used in design:
(1) With no live load on bridge, 30 pounds per square foot on 1.5 times the net area of the side elevation.
(2) With full live load, change the above 30 pounds to 15 pounds per square foot on 1.5 times the net area of bridge and load, and increase the allowable live-load stress by 5 percent.
b. Buildings. The wind pressure and suction (uplift) loads normally used in design, in pounds per square foot of vertical projection, are given in table 147. Wind pressure and suction both act in a direction normal to the plane of a wall or roof. Wind-load requirements are developed locally for areas subjeet to hurrieanes or other violent winds.
c. Stress Increases for Wind Loads. See paragraph 149 for modifications in unit stresses in structural steel, for wind loads alone.

## 144. Impact Loads

No allowance for impact is required for any wood structures, and normally none is required in any other structures except those designed to earry heavy, moving loads. In steel-bridge structures, live-load stresses are modified for impact and similar factors, as follows:

| Surface |  |  |  | Load in pounds per square foot of verticai projection |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Pressure | Suction |
| Exterior walls. | Temporary buildings not used for assembly <br> Permanent buildings $\qquad$ |  |  | $\begin{aligned} & 10 \\ & 20 \end{aligned}$ |  |
| Additional load on interior side of exterior walls. <br> Chimneys | Buildings nominally tight. Buildings between tight and 30 percent open |  |  | 4.5 or | 4. 5 |
|  |  |  |  | 4. 5 to ${ }^{1} 12$ or 4.5 to 19 |  |
|  | Buildings 30 percent or more open.---.-- |  |  | 12 or | 19 |
|  | Square or rectangular- <br> Hexagonal or octagonal <br> Round or elliptical |  |  | 302418 |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| Flat roofs. Pitched roofs. |  |  |  |  | 12 |
|  | Windward side. | Roofs pitched un Roofs pitched $20^{\circ}$ | der $20^{\circ}$ - |  | $\begin{gathered} 12 \\ 12 \cdot \text { to }^{10} 0 \end{gathered}$ |
|  |  | Roofs pitched $30^{\circ}$ | to $60^{\circ}$----- | 0 to ${ }^{19}$ |  |
|  | Leeward side, all pitches--------------- |  |  |  | 9 |
| Bowstring roofs. | Starting at ground level. <br> On elevated supports. |  |  | Pressure | Suction |
|  |  |  |  | 0 to ${ }^{111.4}$ | $\begin{array}{r} 11 \\ 9 \\ 12 \end{array}$ |
|  |  |  |  | $0 \text { to }{ }^{1} 12$(or) | $\begin{aligned} & 12 \text { to } 0 \\ & 11 \text { to } 120 \\ & .9 \end{aligned}$ |
|  |  |  |  |  |  |

[^33]a. Highway Bridges. For impact, increase strcsses by 15 percent of the live-load stress in steel superstructures. No increase is required in substructures.
b. Railroad Bridges. No allowance for impact is required for substructures other than steel towers. For rolling effect in superstructures and steel towers increase stresses 20 percent in the loading from one rail and provide an equal decrease in the loading from the other rail. In addition, for impact, live-load stresses are increased by percentages as follows:
(1) For steam locomotives:
(a) Spans-under 100 feet, $I=80-\frac{L^{2}}{500}$
(b) Spans over 100 feet, $I=\frac{1800}{L-40}+30$
(2) For electric locomotives,
$I=\frac{360}{L}+12.5$. Where $I=$ percentage of live-load stress added for impact and $L$ is span in feet for stringers, floorbeams (this length also applies for subdiagonals of trusses), longitudinal girders, and trusses (for chords and main members).

## 145. Combined Loads

Structures are designed for combinations of dead, live, and other loads given above, at working stresses authorized for the materials used. For combined loads including wind loads, working stresses for certain materials are increased to higher values authorized under those conditions (par. 149) provided the resulting section is adequate for all loads except wind, at normal working stresses.

## Section II. DESIGN FORMULAS

## 146. Formulas For Beam Design

The formulas given apply primarily to vertical shear, bending moments, and deflections. They are useful as reference material in the design of simple beams but the designer considers also the effects of horizontal shear, moving loads, impact, and the like. For additional information see standard handbooks in unit libraries.
a. List of symbols.
$A=$ area of cross section in square inches
$b=$ breadth or width in inches
$c=$ distance, neutral axis to extreme fiber in inches
$d=$ depth in inches
$\Delta=$ deflection
$E=$ modulus of elasticity
$f=$ unit stress in p.s.i.
$f_{h}=$ horizontal shear in p.s.i.
$I=$ moment of inertia
$L=$ span in feet
$l=$ span in inches
$M=$ moment, bending moment
$P=$ concentrated load
$p=$ pressure per unit of area
$R=$ reaction
$r=$ radius of gyration
$S=$ section modulus $=\frac{I}{c}$
$V=$ total vertical shear
$v=$ unit vertical shear
$W=$ total load on one span
$w=$ load per unit of length
$X=$ horizontal axis
$x=$ distance parallel to $X$ axis
$Y=$ vertical axis
$y=$ distance parallel to $Y$ axis
b. Properties of Sections. Areas, moments of inertia, and other properties of seleeted geometrical shapes are given in figurc 70.
c. Beam Formulas for Flexural Stress at Extreme Fiber.

$$
\begin{gathered}
f=\frac{M c}{I}=\frac{M}{S} \\
M=\frac{I f}{c}=S f \\
S=\frac{I}{c}=\frac{M}{f}
\end{gathered}
$$

d. Horizontal Shear Stresses in Beams.
(1) Reetangular beams.

$$
f_{h}=\frac{3}{2} \times \frac{V}{b d}
$$

(2) Stcel I beams.

$$
f_{h}=\frac{V}{\text { web thickness } \times \text { depth between curved fillets }}
$$

(3) Beams of eircular cross section.

$$
f_{h}=\frac{16 V}{3 \pi d^{2}}
$$

e. Reactions, moments, and shears for statically loaded beams are given in figure 71.

Beams Without Lateral Support. Long unsupported or unbraced beams having $\frac{l}{b}$ valỉe greater than 40 are not normally used as load carrying members. These beams should be braced or supported to reduce the value of $\frac{l}{b}$. For investigation of beams where adequate lateral support is not provided, a reduced extremc fiber stress in bending is eomputed from the following:

$$
f=\frac{14,400,000}{l d \div b t}
$$

Where $f=$ allowable stress in psi
$l=$ unsupported length in inches
$b=$ flange width in inches
$t=$ flange thickness in inches
$f$. Continuous Beams. For eontinuous beams with equal spans and uniformly distributed loads, two to five spans, moment and shear coeffieients are given in figure 72.

## 147. Stresses in Rigid Frames

Stresses in rigid frames, for various conditions of statie loading, are given in figure 73.


Figure 70. Properties of sections.

| Circle <br> Axis through center | $\begin{aligned} & A=\frac{\pi d^{\prime}}{4}=\pi R^{\prime \prime}=.785398 d^{\prime}=3.141593 R^{\prime \prime} \\ & c=\frac{d}{2}=R \\ & 1=\frac{\pi d^{\prime}}{64}=\frac{\pi R^{\prime}}{4}=.049087 d^{\prime}=.785398 R^{\prime} \\ & S=\frac{\pi d^{\prime}}{32}=\frac{\pi R^{\prime}}{4}=.098175 d^{2}=.785398 R^{\prime} \\ & r=\frac{d}{4}=\frac{R}{2} \quad \end{aligned}$ |
| :---: | :---: |
| Hollow Circle Axis through center | $\begin{aligned} & A=\frac{n\left(d^{\prime}-d_{1}{ }^{\prime}\right\rangle}{4}=.785398\left(d^{*}-d_{1}\right) \\ & c=\frac{d}{2} \\ & 1=\frac{n\left(d^{\prime}-d_{1}\right)}{64}=.049087\left(d^{\prime}-d_{1}^{\prime}\right) \\ & \mathbf{S}=\frac{n\left(d^{2}-d_{1}^{\prime}\right)}{32 d}=.098175 \frac{d^{4}-d_{1}^{*}}{d} \\ & r=\frac{\sqrt{d^{2}+d_{1}{ }^{2}}}{4} \end{aligned}$ |
| Angle <br> Axis through center of gravity | $\begin{aligned} & A=1(b+c) x=\frac{b^{2}+c t}{2(b+c)} y=\frac{d^{2}+o t}{2(b+c)} \\ & I x=\frac{1}{3}\left[t(d-y)^{4}+b y^{\prime}-o(y-t)^{\prime}\right] \\ & I:=\frac{1}{3}\left[t(b-x)^{\prime}+d x^{\prime}-c(x-t)^{\prime}\right] \\ & I x=M \sin ^{\prime} \theta+h \cos ^{2} \theta+K \sin 2 \theta \\ & I /=M \cos ^{2} \theta+h \sin ^{2} \theta-K \sin 2 \theta \\ & K=\frac{o b c d t}{4(b+c)} K \text { is negotive when heel of } \\ & c . g ., \text { is in } 1 \text { st or 3rde, with reference to } \\ & \text { when in } 2 d \text { or 4th. } \end{aligned}$ |
| Beams and Chonnels <br> Transverse force oblique through c. g. | $\begin{aligned} & l_{1}=I x \sin ^{2} \phi+h \cos ^{2} \phi \\ & l_{1}=I \cdot \cos ^{2} \phi+h \sin ^{2} \cdot \phi \\ & f=M\left(\frac{y}{f} \sin \phi+\frac{x}{h} \cos \phi\right) \end{aligned}$ <br> Where $M$ is bending moment due to force $F$ |

Figure 70-Continued.

Simple beam, unifarmly distributed load.


Simple beam, cancentrated laad at any paint

Equivalent unifarmly distributed laad
$R_{1}=V_{1}$ (max, when $a<b$ )
$=\frac{8 P a b}{l^{-}}$
$R_{1}=V:(\max$ when $a>b)$
$=\frac{\mathrm{Pb}}{\mathrm{l}}$

Mmax (at paint of laad)
M. (when $\times<0$ )

$\Delta \max \left(a t x=\sqrt{\frac{a(a+2 b)}{3}}\right.$ when $\left.a>b\right)=\frac{P a b(a+2 b) \sqrt{27 E(l}+\sqrt{3 a(a b)}}{2}$
$\Delta a$ (at paint af laad)

$$
=\frac{\mathrm{Pa}^{-} \mathrm{b}^{-}}{3 \mathrm{E} \mathrm{I}^{\prime}}
$$

$\Delta x$ (when $x<a$ )

$$
=\frac{\mathrm{Pbx}}{6 \mathrm{Ell}}\left(7^{2}-\mathrm{b}^{2}-\mathrm{x}^{2}\right)
$$

Figure 71. Beam formulas for static loading.

## Beam fixed at ane end, supparted of ather



$$
\begin{array}{ll}
R_{1}=V_{1} & =\frac{P b^{\prime}}{2!^{\prime}}(a+2 l) \\
R_{2}=V_{2} & \\
=\frac{P_{a}}{2^{\prime}}\left(3 I^{\prime}-a^{2}\right)
\end{array}
$$

$M_{1}$ (at paint of laad) $=R_{1} a$

- $M_{2}$ (at fixed end) $=\frac{P a b}{2 l_{2}}(a+1)$
$M$ (when $x<a$ ) $=R_{1} x$
$M x$ (when $x>a)=R_{1} x-P(x-a)$
$=\frac{\mathrm{Pa}}{3 \mathrm{EI}} \frac{\left(l^{2}-a^{2}\right)^{3}}{\left(3 T^{2}-a^{2}\right)^{2}}$
$\triangle \max$ (when $a<.414 l$ of $x=\left\lvert\, \frac{i^{\circ}+a^{\circ}}{3 i^{2}-a^{*}}\right.$ )
$\Delta \max \left(\right.$ when $a>.4141$ ai $x=1 \sqrt{\frac{a}{21+a}}$ )
$\Delta a$ (at paint of load)
$\Delta x$ (when $x<a$ )
$=\frac{P a b^{2}}{6 E I} \sqrt{\frac{a}{21+a}}$
$=\frac{\mathrm{Pa}^{\prime \prime} \mathrm{b}^{*}}{12 \mathrm{E} l^{i}}(3 l+a)$
$=\frac{\mathrm{Pb}^{2} \mathrm{x}}{12 \mathrm{El} \|^{\prime}}\left(3 \mathrm{a} l^{2}-2 l \mathrm{x}^{2}-a x^{2}\right)$
$\Delta \mathrm{x}$ (when $\mathrm{x}>\mathrm{a}$ )
$=\frac{\mathrm{Pa}}{12 E\left(l^{i}\right.}(l-x)^{-}\left(3 I^{-} x-a^{-} x-2 a^{\prime} l\right)$
Figure 31-Continued.

Beam fixed af both ends, unifarmly distributed load.
Equivalent unifarm load (as a simple beam) $=\frac{2 w l}{3}$


$$
\begin{array}{ll}
R=V & =\frac{w l}{2} \\
V & =w\left(\frac{l}{2}-x\right) \\
V_{x} & =\frac{w l^{2}}{12} \\
M \max \text { (at ends) } & =\frac{w l^{2}}{24} \\
M_{1} \text { (at center) } & =\frac{i w}{12}\left(6 l x-l^{2}-6 x^{2}\right) \\
M_{x} & =\frac{w l^{4}}{384 E l} \\
\Delta \max \text { (at center) } & =\frac{w x^{2}}{24 E}(l-x)^{2} \\
\Delta x &
\end{array}
$$

- Beam fixed at both ends, cancentrated load at any point.

$$
\begin{aligned}
& R_{1}=V_{1}(\max \text { when } a<b)=\frac{P b^{*}}{D^{*}}(3 a+b) \\
& R_{:}=V:(\max \text { when } a>b)=\frac{P_{i}^{2}}{F}(a+3 b) \text {, } \\
& M_{1}(\max \text { when } a<b) \quad=\frac{P a b^{2}}{l^{2}} \\
& \text { Mi-imax when } a>b) \quad=\frac{P a^{=} b}{l} \\
& \text { Ma (at point of load) } \quad=\frac{2 \mathrm{~Pa}^{2} b^{2}}{l^{2}} \\
& M \times(\text { when } x<a) \quad=R_{1 x}-\frac{P_{a b}}{l^{2}} \\
& \Delta_{\text {max }}\left(\text { when } a>b \text { at } x=\frac{2 a l}{3 a+b}\right)=\frac{2 P_{a}{ }^{2} b^{2}}{3 E(3 a+b)^{2}} \\
& \Delta a \text { (at paint of load) } \quad=\frac{\mathrm{Po}^{3} b^{3}}{3 E l^{3}} \\
& \Delta x \text { (when } x<a \text { ) }
\end{aligned}
$$

Gantitever beam; uniformly distributed load.


$$
\begin{aligned}
& \text { Equivalent unifarm load (as a simple beain) = } 4 \mathrm{wl} \\
& \begin{array}{ll}
\mathbf{R}^{\circ}=V & =w l \\
V \times & =w x
\end{array} \\
& M \max \left(a t \text { fixed end) }=\frac{w l^{2}}{2}\right. \\
& M x \quad=\frac{w x^{2}}{2} \\
& \Delta \text { max (at free end) }=\frac{\dot{\omega} l^{4}}{8 E I} \\
& \Delta x \\
& =\frac{w}{24 E l}\left(x^{4}-4 l^{1} x+3 l^{4}\right)
\end{aligned}
$$

Figure 71-Continued.

Cantilever beom, concentrated lood at any point

Equivalent unifarm load (as a simple beam) $=\frac{8 \mathrm{~Pb}}{l}$
Equivalent unifarm load (as a simple beam) $=\frac{8 \mathrm{~Pb}}{l}$
$R=V($ when $x<a)=P$
$R=V($ when $x<a)=P$
Mmax (ot fixed end) $=\mathrm{Pb}$
Mmax (ot fixed end) $=\mathrm{Pb}$
$M$ : (when $x>a$ ) $\quad=P(x-0)$
$M$ : (when $x>a$ ) $\quad=P(x-0)$
$\Delta \max$ (at free end) $=\frac{\mathrm{Pb}^{2}}{6 \mathrm{El}}(3 l-\mathrm{b})$
$\Delta \max$ (at free end) $=\frac{\mathrm{Pb}^{2}}{6 \mathrm{El}}(3 l-\mathrm{b})$
$\Delta a\left(\right.$ ot point af lood) $=\frac{\mathrm{Pb}^{\prime}}{3 \mathrm{EI}}$
$\Delta a\left(\right.$ ot point af lood) $=\frac{\mathrm{Pb}^{\prime}}{3 \mathrm{EI}}$
$\Delta \mathrm{x}($ when $\mathrm{x}<\mathrm{a})=\frac{\mathrm{Pb}^{2}}{6 \mathrm{El}}(3 l-3 \mathrm{x}-\mathrm{b})$
$\Delta \mathrm{x}($ when $\mathrm{x}<\mathrm{a})=\frac{\mathrm{Pb}^{2}}{6 \mathrm{El}}(3 l-3 \mathrm{x}-\mathrm{b})$
$\Delta x$ (when $x>a) \quad=\frac{p(l-x)^{2}}{6 E I}(3 b-l+x)$
$\Delta x$ (when $x>a) \quad=\frac{p(l-x)^{2}}{6 E I}(3 b-l+x)$

Figure 71.—Continued
Positive ond Negotive Moments
Coefficients of w $t^{2}$


Figure 72. Moments and shears in continuous beams.
Cancentrated vertical laad.


| General Case | Load in Center $a=b$ |
| :---: | :---: |
| $H=\frac{3 P a b}{2 h /(2 k \div 3)} ; k=\frac{1}{l} \cdot \frac{h}{l}$ | $H=\frac{3 P /}{8 h(2 k+3)} ; k=\frac{I_{1}}{I_{2}} \cdot \frac{h}{l}$ |
| $V_{1}=\frac{P b}{l} V_{1}=\frac{P_{a}}{l}$ | $V_{n}=\frac{P}{2} \quad V_{0}=\frac{P}{2}$ |
| $M_{1}=M_{c}=-H h$ | $M_{1}=M c=-H h$ |

Unifarmly distributed vertical laad.


Figure 73. Stresses in rigid frames.
Cancentrated harizontal lood.


| General Case | Load of Bach |
| :---: | :---: |
| $\begin{aligned} & H=\frac{P_{a}}{2} \cdot \frac{3 h^{2}+k\left(3 h^{2}-a^{2}\right)}{h^{2}(2 k+3)} ; k=\frac{l_{1}}{l_{2}} \frac{h}{l} \\ & V_{1}=V_{1}=\frac{P_{a}}{l} \\ & M_{1}=P_{a}-H_{i}: M_{c}=-H h \end{aligned}$ | $\begin{aligned} & H=\frac{P}{2} \\ & V_{A}=V_{1}=\frac{P h}{l} \\ & M_{1}=+\frac{1}{2} P h_{i} M_{c}=-\frac{1}{2} P h \end{aligned}$ |

Unifarmly distributed harizantal laad.


| General Case. | Side Fully Loaded; c $=$ h |
| :---: | :---: |
| $\begin{aligned} & H=\frac{w\left[6 h^{2}(1+k)\left(b^{2}-a^{-}\right)-k\left(b^{4}-a^{4}\right)\right]}{8 h^{\prime}(2 k+3)} \\ & V_{:}=V_{1}=\frac{w\left(b^{2}-a^{2}\right)}{2 I} k=\frac{L_{1}}{l_{2}} \cdot \frac{h}{T} \\ & M_{1:} V_{1} I I-H h_{;} M c=-H h \end{aligned}$ | $\begin{aligned} & H=\frac{w h}{8} \cdot \frac{6+5 h}{2 k+3} \\ & V_{1}=V_{1}=\frac{w h^{\prime}}{2 \prime} ; k=\frac{l_{1}}{1:} \cdot \frac{h}{l} \\ & M_{11} V_{11}-H h ; M c=-H h \end{aligned}$ |

Figure 73-Continued.

## 148. Stresses in Truss Members

a. Stresses in truss members are found by methods given in standard handbooks in unit libraries. For common types of trusses, stress factors based on symmetrical vertical loads only, and based on equal panel lengths and panel loads, are given in figure 74. In the truss diagrams shown, compression members are indicated by heavy lines, tension members by light lines.
b. Cooper's E-45 loading (fig. 68) produces for each rail the moments, shears, and pier reactions shown in table 148. The values for any other Cooper's loading are directly proportional to those tabulated for Cooper's $\mathrm{E}-45$; e.g., for $\mathrm{E}-30$, multiply the tabulated values by $30 / 45$. The values are adjusted for dead loads and for wind, impact, and other loads as required by paragraphs 141,143 , and 144.

(1) Four-panel Fink truss

Figure 74. Stresses in truss members.


Figure 74-Continued.

R.35P

| Member | Stress equals P times factors below |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | $\begin{gathered} L / h=3 \\ 33^{\circ}-41^{\prime} \end{gathered}$ | $1 / h=3.464$ | $\begin{aligned} & \mathbf{L} / \mathbf{h}=\mathbf{4} \\ & 26^{\circ}-34^{\prime} \end{aligned}$ | $\begin{aligned} & \mathrm{L} / \mathrm{h}=5 \\ & 21^{\circ}-48^{\prime} \end{aligned}$ |
| U1 | 8.49 | 9.63 | 10.96 | 13.49 |
| U2 | 7.94 | 9.13 | 10.51 | 13.11 |
| U3 | 7.39 | 8.63 | 10.06 | 12.74 |
| U4 | 6.83 | 8.13 | 9.61 | 12.37 |
| L1 | 7.17 | 8.44 | 9.90 | 12.61 |
| 12 | 6.15 | 7.23 | 8.48 | 10.81 |
| L3 | 3.60 | 4.16 | 4.80 | 6.00 |
| C1 | 0.83 | 0.87 | 0.89 | 0.93 |
| C 2 | 1.66 | 1.73 | 1.79 | 1.86 |
| T1 | 1.02 | 1.21 | 1.41 | 1.80 |
| T2 | 2.87 | 3.37 | 3.96 | 5.04 |
| T3 | 3.89 | 4.58 | 5.37 | 6.85 |

Figure 74-Continued.


NOTES: Far laads p1, p2, etc., the cuefficients far the chords and diagonals are the some as given for the loads P1, P2, etc. The coefficients far the verticols for loads pl, p2, etc., are given in the supplementory table below the aeneral table.

Figure $74-$ Continued.

Table 148. Moments, Shears, Pier Reactions for Cooper's E-4.5 Loading

| $\underset{\text { (feet) }}{\substack{\text { Span }}}$ | Maximum moment (M) (kipsfoot). | Maximum shear ( $V$ ) |  |  | $\begin{aligned} & \text { Maximum } \\ & \text { pier } \\ & \text { reaction } \\ & (\mathrm{R}) \text { (kips }) \end{aligned}$ | Equivalent u niform load |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\underset{\text { (kips) }}{\text { End }}$ | Quarterpoint (kips) | $\begin{aligned} & \text { Center } \\ & \text { (kips) } \end{aligned}$ |  |  | $\underset{\substack{\text { maximum } \\ \text { end shear } \\ \text { (pound- } \\ \text { foot }}}{\text { For }}$ | For maximum pier rection (pound- foot) |
| 10 | 63.4 | 33.8 | 22.5 | 11.3 | 45. 0 | 5, 063 | 6, 750 | 4,500 |
| 11 | 73.0 | 36.8 | 23.5 | 12.2 | 49. 1 | 4,887 | 6, 705 | 4, 464 |
| 12 | 90.0 | 39.4 | 24.4 | 13. 1 | 52. 6 | 5, 004 | 6, 561 | 4, 374 |
| 13 | 106. 9 | 41. 6 | 25.1 | 13.0 | 55.4 | 5, 063 | 6, 390 | 4, 266 |
| 14 | 123.8 | 43. 4 | 26.6 | 14.6 | 58. 7 | 5, 049 | 6, 210 | 4, 194 |
| 15 | 140. 7 | 45. 0 | 28. 2 | 14. 9 | 61.5 | 5, 004 | 6, 003 | 4, 100 |
| 16 | 157.5 | 57.8 | 29.6 | 15. 4 | 64.0 | 4, 923 | 5,976 | 4,001 |
| 17 | 174. 4 | 50. 3 | 30. 9 | 15. 6 | 66. 2 | 4, 824 | 5, 922 | 3, 893 |
| 18 | 191. 3 | 52.5 | 31. 9 | 15. 7 | 68. 3 | 4, 725 | 5, 841 | 3, 789 |
| 19 | 210. 0 | 54. 5 | 32. 9 | 15. 8 | 70.7 | 4,653 | 5, 733 | 3, 726 |
| 20 | 233. 0 | 56.3 | 33. 8 | 15. 8 | 73. 7 | 4, 644 | 5,625 | 3, 670 |
| 21 | 254. 3 | 57.8 | 35. 3 | 16.3 | -76. 4 | 4, 590 | 5, 613 | 3, 636 |
| 22 | 276. 4 | 59.3 | 36. 8 | 16. 9 | 79.8 | 4,545 | 5,391 | 3, 582 |
| 23 | 298. 6 | 60. 7 | $-38.2$ | 17. 4 | 81. 2 | 4,500 | 5, 274 | 3, 528 |
| 24 | 320. 9 | 62.4 | 39.4 | 17. 8 | 83. 2 | 4, 446 | 5, 198 | 3, 465 |
| 25 | 343. 2 | 63.9 | 40.5 | 18. 2 | 85.1 | 4, 392 | 5, 112 | 3, 402 |
| 26 | 365. 4. | 65.3 | 41.5 | 18.5 | 87.4 | 4,338 | 5, 027 | 3, 362 |
| 27 | 387.7 | 66. 6 n | 42.5 | 19.0 | 90.1 | 4,375 | 4,932 | 3, 339 |
| 28 | 411.2 | 68.0 | 43.4 | 19.3 | 92.5 | 4,221 | 4,851 | 3, 303 |
| 29 | 436. 5 | 69.2 | 44. 2 | 19.6 | 94.9 | 4, 163 | 4,770 | 3, 272 |
| 30 | 461.7 | 70.9 | 45.0 | 19.9 | 97.1 | 4, 104 | 4, 730 | 3, 236 |
| 31 | 487.0 | 72.5 | 45.8 | 20. 4 | 99.5 | 4, 050 | 4,676 | 3, 213 |
| 32 | 512.4 | 73. 9 | 46.6 | 21.1 | 102. 3 | 4,005 | 4, 617 | 3, 200 |
| 33 | 537.7 | 75.3 | 47.3 | 21.6 | 105. 0 | 3,951 | 4,563 | 3, 182 |
| 34 | 563. 2 | 76.6 | 48. 2 | 22.1 | 107. 5 | 3, 897 | 4,505 | 3, 159 |
| 35 | 588.4 | 77.9 | 49.0 | 22.6 | 109. 8 | -3, 848 . | 4,451 | 3, 137 |
| 36 | 617.2 | 79.4 | 49.6 | 23. 2 | 112.0 | 3, 816 | 4, 410 | 3,110 |
| 37 | 646. 1 | 80.8 | - 50.4 | 23.6 | 114. 2 | 3, 780 | 4, 370 | 3, 087 |
| 38 | 675.0 | 82.3 | 51.0 | 23. 9 | 116. 7 | 3, 753 | 4, 329 | 3, 069 |
| 39. | 705. 0 | 83.6 | 51.8 | 24. 4 | 119. 1 | 3, 721 | 4, 288 | 3, 051 |
| 40 | 737. 2 | 84. 9 | 52.7 | 24. 8 | 121.5 | 3,690 | 4, 244 | 3,038 |
| 42 | 802.8 | 87.8 | 54. 2 | 25. 5 | 126. 2 | 3, 636 | 4, 185 | 3,006 |
| 44 | 868. 1 | 90.6 | 55. 7 | 26.1 | 131.0 | 3, 582 | 4, 122 | 2,979 |
| 46 | 933.6 | 93.2 | 57.1 | 26.6 | 135. 8 | 3, 537 | 4,050 | 2, 952 |
| 48 | 998. 6 | 95. 7 | 58.6 | 27. 2 | 140. 4 | 3, 483 | 3, 987 | 2, 925 |
| 50 | $\cdots 1,069.7$ | 98. 1 | 60. 1 | 28.0 | 144. 9 | 3, 429 | 3, 924 | 2,898 |
| 55 | 1, 256.5 | 104. 2 | 62. 9 | 29. 7 | 157.9 | 3, 339 | 3, 794 | 2, 876 |
| 60 | 1, 462.] | 110.3 | , 67.7 | 31.4 | 172. 4 | 3, 249 | 3, 672 | 2, 876 |
| 65 | 1, 684. 7 | 116. 7 | 70. 9 | 33.1 | 186.0 | 3, 195 | 3, 591 | 2, 862 |
| 70 | 1, 921.0 | 124. 3 | 74.2 | 34. 6 | 199. 2 | 3, 137 | 3,551 | 2, 844 |
| 75 | 2, 166. 6 | 132. 4 | 77. 1 | 36. 4 | 211.7 | 3, 087 | 3, 528 | 2, 822 |
| 80 | 2, 432. 5 | 139. 8 | 80.6 | 37. 9 | 223. 7 | 3, 038 | 3,497 | 2, 799 |
| 85 | $2,707.7$ | 147. 1 | 84. 5 | 39. 7 | 234. 7 | 3, 002 | 3, 465 | 2, 763 |
| 90 | 3, 004. 3 | 154. 4 | 88.6 | 41. 3 | 245.9 | 2,966 | 3, 429 | 2,732 |
| 95 | 3, 306.9 | 161. 6 | 92. 8 | 42.8 | 256. 6 | 2,934 | 3,402 | 2, 700 |
| 100 | 3, 622. 4 | 168. 8 | 97. 4 | 44. 3 | 266. 9 | 2, 898 | 3, 375 | 2, 669 |
| 105 | 3, 979. 8 | 175. 6 | 101. 4 | 45. 6 | 276.8 | 2,894 | 3, 334 | 2,637 |
| 110 | 4,372. 7 | 182.3 | 105. 6 | 47: 1 | 286.7 | 2,889 | 3, 312 | 2,606 |

- Table 148. Moments, Shears, Pier Reactions for Cooper's E-45 Loading-Con.

| $\underset{\text { (feet) }}{\text { Span }}$ | Maximum ${ }_{(M)}^{\text {moment }}$ (kipsfoot) | Maximum shear ( $V$ ) |  |  | $\begin{gathered} \text { Maximum } \\ \text { pieaction } \\ \text { (R) (kips) } \end{gathered}$ | Equivalent uniform load |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\underset{\text { (kips) }}{\text { End }}$ | Quarter- point (kips) | $\begin{aligned} & \text { Center } \\ & \text { (kips) } \end{aligned}$ |  | $\underset{\substack{\text { marimum } \\ \text { moment } \\ \text { (pound- } \\ \text { foot) }}}{ }$ |  | $\begin{gathered} \text { For } \\ \text { maximum } \\ \text { pier } \\ \text { reaction } \\ \text { (pound- } \\ \text { foot) } \end{gathered}$ |
| 115 | 4, 775. 6 | 188. 9 | -109. 7 | 48. 5 | 296. 1 | 2, 889 | 3, 285 | 2, 574 |
| 120 | $5,190.8$ | 195. 4 | 113.8 | 50.0 | 306. 0 | 2, 885 | 3, 258 | 2, 552 |
| 125 | 5,621. 0 | 201. 8 | 127.8 | 51.8 | 316. 1 | 2, 880 | 3, 231 | 2, 529 |
| 150 | 7, 945. 1 | 233. 3 | 137.0 | 61. 2 - | 366. 0 | 2, 826 | 3, 110 | 2, 439 |
| 175 | 10,521: 5 | 263.8 | 155. 6. | 70. 4 | 418. 1 | 2, 750 | 3, 015 | 2, 390 |
| 200 | 13, 357. 1 | 293. 7 | 172.6 | 79. 2 | 471. 4 | 2, 669 | 2,939 | 2, 358 |
| 250 | 19,791. 5 | 362.4 | 206. 6 | 95.7- | 579.6 | 2,534 | 2,817 | 2,318 |

$c$. The section modulus may be determined from-

$$
S=\frac{M_{t o t}}{f}
$$

where-
$S=$ section modulus required for stringers under one rail and is measured in inches ${ }^{3}$.
$M_{t o t}=$ total-maximum bending moment in inch-pounds.
$f=$ allowáble bending stress in p.s.i.
Table 149 gives values for $S$ for various spans and corresponding values of $M_{t o t}$.

Table 149. Section Modulus and Shear

| Span (feet) | MTOT <br> (feet $K$ ) | $\begin{aligned} & \text { SREQ } \\ & (\text { in } S) \end{aligned}$ | $\underset{\substack{\text { Mhear } \\(K)}}{\substack{\text { Maximum }}}$ | Span (feet) | $\underset{(\text { feet } K)}{\text { MTOTT}}$ | $\underset{(\text { in } S)}{\text { SREQ }}$ | $\underset{\substack{\text { Maximuram } \\(K)}}{\substack{\text { Maximen }}}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 202. 1 | 90 | 80.7 |  | 1462.5 | 650 | 171. 4 |
|  | 222. 8 | 99 | 85. 4 | 38 | 1526.. 9 | 679 | 174. 4 |
| 12. | 255. 8 | - 114 | 89. 4 | 39 | 1594. 3 | 709 | 177.3 |
| 13. | 290. 0 | 129 | -92.8 | $40^{\circ}$ | 1663. 2 | 739 | 179.8 |
| 14 | 323. 6 | 144 | 95. 7 | 42 | 1805. 1 | 802 | 186. 1 |
|  | 348. 6 | 155 | 98. 3 | 44 | 1947. 2 | 865 | 192. 2 |
| 16 | 393. 5 | 175 | 103. 5 | 46 | 2097. 8 | 932 | 198. 1 |
|  | $\cdots 428.4$ | 190 | 108. 0 | 48 | 2240.4 | 996 | 203. 7 |
| 18 | 463. 8 | 206 | 112. 1 | 50 | 2400.1 | 1067 | 208. 8 |
| 19 | 502. 2 | 223 | 115.'6 | 52 | 2566 | 1140 | 213. 9 |
|  | 576. 0 | 256 | 121. 7 | 54 | 2744 | 1219 | 220.1 |
| 21 | 620.4 | 275 | 124. 9 | 56 | 2923 | 1299 | 225. 7 |
| 22 | 665. 3 | 295 | 127. 8 | 58 | 3106 | 1380 | 231. 1 |
| 23. | 712. 9 | 316 | 130. 1 | 60 | 3305 | 1469 | 236. 8 |
| 24- | 758. 5 | 336 | 133. 2 | 65 | 3815 | 1695 | 251. 9 |
| 25. | 806. 2 | 358 | 136. 2 | 70 | 4352 | 1934 | 268. 3 |
| 26. | 855. 1 | 380 | 138. 9 | 75 | 4938 | 2195 | 285. 9 |
| 27 | 901.7 | 401 | 171.9 | 80 | 5545 | 2464 | 301. 8 |
| 28 | 952. 6 | 423 | 144. 5 | 85 | 6167 | 2741 | 317.6 |
| 29 | 1005. 9 | 447 | 146. 5 | 90 | 6856 | 3047 | 333. 1 |
| 30 | 1060. 7 | 471 | 150. 4 | 95 | 7544 | 3353 | 348. 1 |

Table 149. Section Modulus and Shear-Continued

| $\underset{\text { (feet) }}{ }$ | $\underset{(\text { feet }+ \text { ( }}{\text { MTTT }}$ | $\begin{aligned} & \text { SREQ } \\ & (\text { in } S) \end{aligned}$ | $\underset{\substack{\text { Maximum } \\(+)}}{\text { Mhear }}$ | $\underset{\text { (feet) }}{\text { Span }}$ | $\underset{(\text { feet }+ \text { ) }}{\text { MTOTT }}$ | $\underset{(\operatorname{In} S)}{\operatorname{SRE}}$ | $\begin{gathered} \text { Maximum } \\ \text { shear } \\ (+) \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1113. 8 | 495 | 153. 5 | 100 | 8283 | 3681 | 362. 9 |
|  | 1168. 3 | 519 | 156. 5 | 105 | 9095 | 4042 | 377.5 |
| 33. | 1225. 2 | 544 | 159. 5 | 110 | 9975 | 4433 | 392. 0 |
| 34. | 1279. 9 | 569 | 162.3 | 115 | 10886 | 4838 | 406. 9 |
| 35. | 1337. 1 | 594 | 165.0 | 120. | 11817 | 5252 | 421. 4 |
| 36 | 1400. 6 | 622 | 168.2 | 125. | 12813 | 5695 | 436.5 |

## Section III. STRUCTURAL STEEL

## 149. Working Stresses

a. Basic Stresses. For permanent construction, the allowable unit stresses are given in the Manual of the American Institute of Steel Construction. For temporary buildings and for military construction in a theater of operations, the allowable unit stresses in structural steel, rivets, bolts, and welds are as follows (except as modified by $b$ below, and unless modifications are required due to the use of steel of specifications which differ from those in the manual referred to above).
(1) Tension.



(c) Butt welds, section through throat

20, 000
(2) Compression.

Pounds per square inch
(a) Plate girders stiffeners, gross section 27, 000
(b) Columns, axial compression, gross section, for values of $\frac{1}{r}$ not over 140 :

> Riveted ends
> $21,300-3 / 8\left(\frac{1}{r}\right)^{2}$
> Pinned ends $21 ; 300-1 / 2\left(\frac{1}{r}\right)_{2}$

$$
\begin{aligned}
& \text { Where } \begin{aligned}
1 & =\text { unsupported lengths in inches } \\
r & =\text { least radius of gyration in } \\
& \text { inches }
\end{aligned}
\end{aligned}
$$

(c) Butt welds, section through throat (crushing)

24,000
(3) Bending.

Pounds per square inch
(a) Tension on extreme fibers of rolled sections, plate girders, and built-up members

27,000
(b) Compression on cxtreme fibers of rolled sections, plate girders, and built-up members:
For $\frac{1}{b}$ less than $15 \ldots-\ldots-1 .-27,000$
For $\frac{1}{b}$ values between 15 and $40 \ldots \ldots 27,000-\ldots \frac{15}{2}\left(\frac{1}{b}\right)^{2}$
Where $1=$ laterally unsuppor'ted length in inches
$b=$ flange width in inches
(c) Butt welds. Stresses due to bending shall not exceed those prescribed above for tension and compression, respectively.
(4) Shear.
Pounds per
(a) Rive a
(b) Girder web, gross section $\ldots \ldots \ldots$.......................... 16, 500
(c) Turned bolts in reamed holes_-................... 16, 500
(d) Unfinished bolts $\ldots \ldots \ldots \ldots \ldots$.................................... 12, 000
(e) Weld metal, on section through throat of fillet weld or on faying surface area of plug or slot weld - - - 15,000
Note. Stress in a fillet weld shall be considered as shear on the throat, for any direction of the applied stress. Neither filled nor fillet-welded plug or slot welds shall be assigned any values in resistanee to stress other than shear.


(d) Contact area:

1. Milled stiffeners and other milled surfaces----- 30,000

(e) Expansion rollers or rockers (pounds per linear inch) in which $d$ is diameter of roller or rocker in inches
600 d
b. Stresses for Wind Loads. All allowable stresses given in a above are increased 30 percent but not to exceed 27,000 pounds per square inch, for members subject to wind loads, provided the sections thus determined are adequate at normal stresses for all loads except wind, and including impact (if any).
c. Bearing on Masonry. $\begin{gathered}\text { Poundsper } \\ \text { square inch }\end{gathered}$




d. Stresses in Web Crippling. To avoid web crippling, beams are designed so the compression stress in the web at the toe of the fillet, resulting from reactions or concentrated loads, shall not exceed 24,000 pounds per square inch. These stresses are figured as follows, for webs without stiffeners:

$$
\begin{aligned}
& \text { Maximum end reaction in kips }=24 t(a+k) \\
& \text { Maximum interior load in kips }=24 t\left(a^{1}+2 k\right)
\end{aligned}
$$

Where $t=$ web thickness in inches
$k=$ distance from outer face of flange to toe of fillet, in inches $a^{1}=$ length of concentrated load bearing, in inches
Where the above values are exceeded, either the webs of the beams are reinforced with stiffener angles or the bearing area is increased.
e. Beams Without Lateral Support. A beam is considered to have adequate lateral support if its top flange is embedded about 1 inch in a concrete slab extending over the beams of a floor system. A beam not thus supported carries its full load if its value for $\frac{l d}{b t}$, an expression used in the formula below, does not exceed 400; or if it is braced adequately with steel struts at intervals as required to keep the value less than 400 . If adequate lateral support is not provided, a reduced extreme fiber stress in bending is computed from the following:

$$
\begin{aligned}
& \text { for } \frac{l d}{b t} \text { values between } 400 \text { and } 1000, f=34,000-17.7\left(\frac{l d}{b t}\right) \\
& \text { for } \frac{l d}{\bar{b} t} \text { values above } 1000, f=\frac{16,400,000}{\frac{l d}{b t}}
\end{aligned}
$$

Where $\quad f=$ allowable stress in pounds per square inch
$l=$ unsupported length in inches
$d=$ depth of beam in inches
$b=$ flange width in inches
$t=$ flange thickness in inches
150. Weights and Areas of Bars and Plates

Table 150. Weights and Areas of Bars and Plates

| Size or thickness (inches) |  | Square and round bars |  |  |  | Plates 1 foot wide |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Weigit (pounds per foot) |  | Area (square inehes) |  | Weight (pounds jer foot) | $\begin{aligned} & \text { A rea } \\ & \text { (square } \\ & \text { inches) } \end{aligned}$ |
|  |  | Square | Round | Square | Round |  |  |
| $\cdots 1 / 4$ |  | 0.213 | 0. 167 | 0.0625 | 0.0491 | 10. 20 | 3. 00 |
| 3/8 |  | . 478 | . 376 | 1406 | . 1105 | 15. 30 | 4. 50 |
| 1/2 |  | . 850 | . 668 | . 2500 | . 1963 | 20. 40 | 6. 00 |
| 5/8 |  | 1. 328 | 1. 403 | - . 3906 | . 3068 | 25. 50 | 7. 50 |
| $3 / 4$ |  | 1. 913 | 1. 502 | . 5625 | . 4418 | 30. 60 | 9. 00 |
| 7/8 |  | 2. 603 | 2. 044 | 7656 | . 6013 | 35. 70 | 10. 50 |
| 1. |  | 3. 400 | 2. 670 | 1. 0000 | . 7854 | 40.80 | 12. 00 |
| 118 |  | 4. 303 | 3. 380 | 1. 2656 | . 9940 | 45. 90 | 13. 50 |
| 11/4 |  | 5. 313 | 4. 172 | 1. 5625 | 1. 2272 | 51.00 | 15. 00 |
| $11 / 2$ |  | 7. 650 | 6. 008 | 2. 2500 | 1. 7671 | 61. 20 | 18. 00 |
| 2 |  | ${ }^{13} 13.600$ | 10. 681 | 4. 00 | 3. 1416 | 81.60 | 24. 00 |
| 21/2 |  | 21. 250 | 16. 690 | 6. 25 | 4. 9087 | 102. 00 | 30. 00 |
| 3. |  | 30.600 | 24.033 | 9. 00 | 7. 0686 | 122. 40 | 36. 00 |
| $31 / 2$ |  | 41. 65 | 32. 71 | 12. 25 | 9. 621 | 142. 80 | 42. 00 |
| 4 |  | . 54.40 | 42. 73 | 16.00 | 12. 566 | 163. 20 | 48. 00 |
| Size or th | ness |  |  |  |  |  |  |
| (millimeters) | (inches) |  |  |  |  |  |  |
| 5. - - - | 0. 20 | . 136 | . 103 | $\cdots .04$ | . 03 | 7. 990 | 2. 35 |
|  | . 24 | . 204 | . 149 | . 06 | . 05 | 9.622 | 2. 83 |
|  | . 28 | . 272 | . 203 | . 08 | . 06 | 11. 254 | 3. 31 |
| 8. | . 32 | . 340 | . 265 | . 10 | . 08 | 12. 852 | 3. 78 |
| 10. | . 39 | . 544 | . 415. | ... 16 | . 12 | 16. 082 | 4. 73 |
| 12 | . 47 | . 748 | . 597 | . 22 | . 17 | 19. 244 | 5. 66 |
| 14----- | $\therefore 55$ | 1. 020 | . 813 | . 30 | . 24 | 22. 474 | 6. 61 |
| 16 | . 63 | 1. $258{ }^{\circ}$ | - 1. 062 | . 37 | . 31 | 25. 704 | 7. 56 |
|  | . 71 | 1. 700 | 1. 344 | . 50 | . 40 | 28. 934 | 8. 51 |
| 20_-.-...- | . 79 | 2. 108. | 1. 660 | . 62 | . 49 | -32.096 | 9. 44 |
| 22. | . 87 | 2. 550 | 2. 003 | . 75 | . 59 | 35. 326 | 10.39 |
| 24---.-.-- | $\therefore 94$ | 3. 026 | 2. 386 | . 89 | . 69 | 38. 556 | 11.34 |
| 26------- | 1. 02 | 3. 570 | 2. 802 | 1. 05 | . 82 | 42. $60 \dot{2}$ | 12. 53 |
| 28-- | 1. 10 | 4. 148 | 3. 246 | 1. 22 | . 95 | 44. 948 | 13. 22 |
| 30. | 1. 18 | 4. 760 | 3. 730 | 1. 40 | 1. 09 | 48. 178 | 14. 17 |
| 32. | 1. 26 | 5. 406 | 4. 240 | 1. 59 | 1. 25 | 51. 408 | 15. 12 |
| 34-------- | 1. 34 | 6. 086 | 4. 791 | * 1. 79 | 1. 41 | 54. 638 | 16. 07 |
| 36------- | 1. 42 | 6. 834 | 5. 369 | 2. 01 | 1. 58 | 57.800 | 17. 00 |
| 38. | 1. 50 | 7. 616 | 5. 981 | 2. 24 | 1. 77 | 61.030 | - 17. 95 |
| 40-.----- | 1. 57 | 8. 432 | 6. 633 | 2. 48 | 1. 94 | 64. 260 | 18. 90 |
| 45......-- | 1. 77 | 10. 676 | 8. 400 | 3. 14 | 2. 46 | 72. 284 | 21. 26 |
| 50-------- | $1 . .97$ | 13. 192 | 10. 349 | 3. 88 | 3. 05 | 80.342 | 23. 63 |

[^34]
## 151. Dimensions and Properties of U.S. Sections

Tables 151 to 154 inclusive are reprinted from "Steel Construction" by permission of the American Institute of Steel Construction (copyright 1947). The WF and angle tables are abridged listings.
a. WF Shapes.


| Nominal stze | Welght Der foot | Aren | Depth | Flange |  | Weh thick-ness | Axis X-X |  |  | Axis $\mathrm{Y}-\mathrm{Y}$ |  |  | Gage |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Width | Thickness |  | I | S | r | I | S | r |  |
| In. | Lb | In. | In. | In. | 1 n . | In. | In. | In. | In. | In. | In. | In. | In. |
| $36 \times 161 / 2$ - | 230 | 67. 73 | 35. 88 | 16. 475 | 1. 260 | . 765 | 14988. 4 | 835. 5 | 14. 88 | 870. 9 | 105. 7 | 3. 59 | 51/2 |
| $36 \times 12$ - | 150 | 44. 16 | 35. 84 | 11.972 | . 940 | . 625 | 9012. 1 | 502. 9 | 14. 29 | 250.4 | 41. 8 | 2. 38 | 51/2 |
| $33 \times 111 / 2 \ldots$ | 130 | 38. 26 | 33. 10 | 11. 510 | . 855 | . 580 | 6699.0 | 404. 8 | 13. 23 | 201. 4 | 35.0 | 2. 29 | 51/2 |
| $30 \times 15$ - | 172 | 50. 65 | 29.88 | 14. 985 | 1. 065 | . 655 | 7891.5 | 528. 2 | 12. 48 | 550. 1 | 73.4 | 3. 30 | $51 / 2$ |
| $30 \times 101 / 2 \ldots$ | 108 | 31. 77 | 29. 82 | 10. 484 | 760 | 548 | 4461.0 | 299. 2 | 11. 85 | 135. 1 | 25. 8 | 2. 06 | 51/2 |
| $27 \times 10$. | 94 | 27. 65 | 26. 91 | 9. 990 | 747 | . 490 | 3266. 7 | 242. 8 | 10. 87 | 115. 1 | 23. 0 | 2. 04 | 51/2 |
| $24 \times 12$ | 100 | 29. 43 | 24. 00 | 12. 000 | . 775 | 468 | 2987. 3 | 248. 9 | 10.08 | 203.5 | 33.9 | 2. 63 | 51/2 |
| $24 \times 9$ | 76 | 22. 37 | 23. 91 | 8. 985 | . 682 | . 440 | 2096. 4 | 175. 4 | 9. 68 | 76.5 | 17. 0 | 1. 85 | 51/2 |
| $21 \times 81 / 4$--- | 62 , | 18. 23 | 20. 99 | 8. 240 | . 615 | . 400 | 1326. 8 | 126. 4 | 8.53 | 53.1 | 12. 9 | 1. 71 | 512 |
| $18 \times 71 / 2 \ldots$ | 50 | 14. 71 | 18. 00 | 7. 500 | 570 | . 358 | 800.6 | 89. 0 | 7. 38 | 37. 2 | 9. 9 | 1. 59 | $31 / 2$ |
| $16 \times 7$ | 36 | 10. 59 | 15. 85 | 6. 992 | . 428 | . 299 | 446. 3 | 56.3 | 6. 49 | 22. 1 | 6. 3 | 1. 45 | $31 / 2$ |
| $14 \times 63 / 4-\ldots$ | 30 | 8. 81 | 13. 86 | 6. 733 | . 383 | 270 | 289. 6 | 41. 8 | 5. 73 | 17. 5 | 5. 2 | 1. 41 | $31 / 2$ |
| $12 \times 12 \ldots$ | 65 | 19.11 | 12. 12 | 12. 000 | . 606 | 390 | 533. 4 | 88.0 | 5. 28 | 174. 6 | 29.1 | 3. 02 | 51/2 |


| $12 \times 6 \not 12 \ldots-{ }^{\text {a }}$ | 27 | 7. 97 | 11. 95 | 6. 500 | . 400 | . 240 | 204. 1 | 34.1 | 5. 06 | 16. 6 | 5. 1 | 1. 44 | $31 / 2$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $10 \times 10$--- | 49 | 14. 40 | 10. 00 | 10. 000 | . 558 | . 340 | 272. 9 | 54. 6 | 4. 35 | 93.0 | 18. 6 | 2. 54 | 51/2 |
| $10 \times 53 / 4 \ldots$ | 21 | 6. 19 | 9. 90 | 5. 750 | . 340 | . 240 | 106. 3 | 21. 5 | 4. 14 | 9. 7 | 3. 4 | 1. 25 | $23 / 4$ |
| $8 \times 8$. | 31 | 9. 12 | 8.00 | 8. 000 | . 433 | . 288 | 109. 7 | 27. 4 | 3. 47 | 37. 0 | 9. 2 | 2. 01 | 51/2 |
| $8 \times 61 / 2---$ | 24 | 7. 06 | 7. 93 | 6. 500 | . 398 | 245 | 82. 5 | 20. 8 | 3. 42 | 18. 2 | 5. 6 | 1. 61 | 31/2 |
| $8 \times 51 / 4---$ | 17 | 5.00 | 8. 00 | 5. 250 | . 308 | . 230 | 56. 4 | 14. 1 | 3. 36 | 6. 7 | 2. 6 | 1. 16 | 23/4 |
| $6 \times 6$ | 25 | 7. 37 | 63.7 | 8. 080 | . 456 | . 320 | 53.5 | 16. 8 | 2. 69 | 17. 1 | 5. 6 | 1. 52 | 31/2 |
| $4 \times 4$ | 13 | 3. 82 | 4. 16 | 4. 060 | . 345 | 280 | 11. 3 | 5. 45 | 1. 72 | 3. 76 | 1. 85 | 99 | 2 L 4 |



| Nominal size | Weight per foot | Area | Depth | Flange |  | Web thickness | Axis X-X |  |  | AxIS Y-Y |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Width | Thickness |  | 1 | S | r | 1 | S | r |
| In. | Lb. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| $24 \times 77 / 8-----$ | 120. 0 | 35. 13 | 24. 00 | 8. 048 | 1. 102 | 0. 798 | 3010. 8 | 250.9 | 9.26 | 84.9 | 21. 1 | 1. 56 |
|  | 105. 9 | 30. 98 | 24. 00 | 7. 875 | 1. 102 | . 625 | 2811.5 | 234. 3 | 9. 53 | 78.9 | 20.0 | 1. 60 |
| 24×7------- | 100. 0 | 29. 25 | 24. 00 | 7. 247 | . 871 | . 747 | 2371. 8 | 197.6 | 9. 05 | 48.4 | 13. 4 | 1. 29 |
|  | 90.0 | 26. 30 | 24. 00 | 7. 124 | . 871 | . 624 | 2230.1 | 185. 8 | 9.21 | 45. 5 | 12. 8 | 1. 32 |
|  | 79.9 | 23. 33 | 24. 00 | 7. 000 | . 871 | . 500 | 2087. 2 | 173.9 | 9.46 | 42. 9 | 12. 2 | 1. 36 |
| $20 \times 7$--------- | 95. 0 | 27. 74 | 20.00 | 7. 200 | . 916 | . 800 | 1599. 7 | 160. 0 | 7. 59 | 50. 5 | 14. 0 | 1. 35 |
|  | 85.0 | 24. 80 | 20.00 | 7. 053 | . 916 | . 653 | 1501. 7 | 150. 2 | 7. 78 | 47. 0 | 13. 3 | 1. 38 |
| $20 \times 61 / 4-\cdots-\cdots$ | 75. 0 | 21. 90 | 20.00 | 6. 391 | . 789 | . 641 | 1263. 5 | 126. 3 | 7. 60 | 30. 1 | 9. 4 | 1. 17 |
|  | 65. 4 | 19.08 | 20.00 | 6. 250 | . 789 | . 500 | 1169. 5 | 116.9 | 7. 83 | 27.9 | 8. 9 | 1. 21 |
| 18×6.------- | 70.0 | 20. 46 | 18. 00 | 6. 251 | . 691 | . 711 | 917.5 | 101. 9 | 6. 70 | 24.5 | 7. 8 | 1. 09 |
|  | 54.7 | 15. 94 | 18.00 | 6. 000 | . 691 | . 460 | 795. 5 | 88. 4 | 7. 07 | 21. 2 | 7. 1 | 1. 15 |
| $15 \times 51 / 2-$ | 50.0 | 14. 59 | 15. 00 | 5. 640 | . 622 | . 550 | 481. 1 | 64.2 | 5. 74 | 16. 0 | 5. 7 | 1. 05 |
|  | 42. 9 | 12. $49^{\circ}$ | 15. 00 | 5. 500 | . 622 | . 410 | 441. 8 | 58. 9 | 5. 95 | 14.6 | 5. 3 | 1. 08 |


c. American Standard Channels.

Table 153. American Sicndard Channels

| Nominal size | Weight per foot | Area | Depth | Flange |  | Welb Thiek-ness | Axis $\mathbf{N}-\mathbf{X}$ |  |  | Axis $\mathrm{Y}-\mathrm{Y}$ |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Width | A verage thickness |  | I | S | r | I | S | r | x |
| In. | Lb. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| $18 \times 4{ }^{1}$ | 58.0 | 16. 98 | 18. 00 | 4. 200 | 0. 625 | 0. 700 | 670.7 | 74. 5 | 6. 29 | 18. 5 | 5. 6 | 1. 04 | 0. 88 |
|  | 51. 9 | 15. 18 | 18. 00 | 4. 100 | 625 | 600 | 622. 1 | 69.1 | 6. 40 | 17. 1 | 5. 3 | 1. 06 | . 87 |
|  | 45. 8 | 13. 38 | 18. 00 | 4. 000 | . 625 | . 500 | 573. 5 | 63. 7 | 6. 55 | 15. 8 | 5. 1 | 1. 09 | . 89 |
|  | 42. 7 | 12. 48 | 18.00 | 3. 950 | . 625 | . 450 | 549.2 | 61. 0 | 6. 64 | 15. ${ }^{\text {' }}$ | 4. 9 | 1. 10 | . 90 |
| $15 \times 3 / 8 \ldots \ldots$ | 50.0 | 14. 64 | 15. 00 | 3. 716 | . 650 | 716 | 401. 4 | 53.6 | 5. 24 | 11. 2 | 3. 8 | . 87 | 80 |
|  | 40. 0 | 11. 70 | 15. 00 | 3. 520 | . 650 | 520 | 346. 3 | 46. 2 | 5. 44 | 9. 3 | 3. 4 | . 89 | 78 |
|  | 33. 9 | 9. 90 | 15.00. | 3. 400 | . 650 | . 400 | 312.6 | 41.7 | 5. 62 | 8. 2 | 3. 2 | . 91 | . 79 |
| $12 \times 3$ | 30. 0 | 8. 79 | 12. 00 | 3. 170 | . 501 | 510 | 161. 2 | 26.9 | 4. 28 | 5. 2 | 2. 1 | 77 | :. 68 |
|  | 25. 0 | 7. 32 | 12. 00 | 3. 047 | 501 | . 387 | 143. 5 | 23.9 | 4. 4.3 | 4. 5 | 1. 9 | . 79 | . 68 |
|  | 20. 7 | 6. 03 | 12.00 | 2. 940 | . 501 | 280 | 128. 1 | 21. 4 | 4. 61 | 3. 9 | 1. 7 | . 81 | . 70 |



[^35]
## d. Selected Angles.



Table 154. Selected Angles

| Size | Thickness | Weight perft.-lb. | $\begin{gathered} \text { Area } \\ \text { (sq.in.) } \end{gathered}$ | Axis $\mathbf{X}-\mathbf{X}$ |  |  | Axis Y-Y |  |  | $\begin{aligned} & \text { Axis } \\ & \mathrm{Z}-\mathrm{Z} \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | I | S | r | 1 | S | r | r |
|  |  |  |  | Inches | Inches | Inches | Inches | Inches | Inches | Inches |
| $8 \times 8$ | 1 | 51. 0 | 15. 00 | 89. 0 | 15. 8 | 2. 44 |  |  |  | 1. 56 |
| $6 \times 6$ | 7/8 | 33. 1 | 9. 73 | 31. 9 | 7. 6 | 1. 81 |  |  |  | 1. 17 |
| $5 \times 5$ | 3/4 | 23.6 | 6. 94 | 15. 7 | 4. 5 | 1. 51 | $S$ |  | A | . 97 |
| $4 \times 4$ | 1/2 | 12.8 | 3. 75 | 5. 6 | 2. 0 | 1. 22 | A | A | $\boldsymbol{X}$ | 78 |
|  | 3/8 | 9. 8 | 2. 86 | 4. 4 | 1. 5 | 1. 23 | $M$ | $S$ | $I$ | 79 |
|  | 5/18 | 8. 2 | 2. 40 | 3. 7 | 1. 3 | 1. 24 | $E$ |  | $S$ | 79 |
| $31 / 2 \times 31 / 2-$ | 5/16 | 7. 2 | 2. 09 | 2. 5 | . 98 | 1. 08 |  |  |  | 69 |
| 3×3--- | 5/16 | 6. 1 | 1. 78 | 1. 5 | . 71 | . 92 |  |  | $X-X$ | 59 |
| $2 \times 2$ | 1/4 | 3. 19 | . 94 | . 35 | . 25 | . 61 |  |  |  | 39 |
| $8 \times 6$ | $3 / 4$ | 33. 8 | 9. 94 | 63. 4 | 11. 7 | 2. 53 | 30.7 | 6. 9 | 1. 76 | 1. 29 |
| $6 \times 4$ | 1/2 | 16. 2 | 4. 75 | 17. 4 | 4. 3 | 1. 91 | 6. 3 | 2. 1 | 1. 15 | 87 |
|  | 3/8 | 12. 3 | 3.61 | 13. 5 | 3. 3 | 1. 93 | 4. 9 | 1. 6 | 1. 17 | 88 |
| $5 \times 31 / 2-$ | 3/8 | 10. 4 | 3. 05 | -7.8 | 2.3 | 1. 60 | 3. 2 | 1. 2 | 1. 02 | 76 |
| - | 5/16 | 8. 7 | 2. 56 | 6. 6 | 1. 9 | 1. 61 | 2. 7 | 1. 0 | 1. 03 | 76 |
| $5 \times 3$ | $3 / 8$ | 9. 8 | 2. 86 | 7. 4 | 2. 2 | 1. 61 | 2. 0 | . 89 | . 84 | 65 |
|  | 5/16 | 8. 2 | 2. 40 | 6. 3 | 1. 9 | 1. 61 | 1. 8 | 75 | . 85 | 66 |
| $4 \times 3$ | 3/8 | 8. 5 | 2. 48 | 4. 0 | 1. 5 | 1. 26 | 1. 9 | 87 | . 88 | 64 |
|  | 5/10 | 7. 2 | 2. 09 | 3. 4 | 1. 2 | 1. 27 | 1. 7 | 73 | . 89 | 65 |
| 3 $1 / 2 \times 3 \ldots$ | 5/16 | 6. 6 | 1. 93 | 2. 3 | . 95 | 1. 10 | 1. 6 | 72 | . 90 | . 63 |

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$e$. Steel Rails. Under the policies of the Department of Defense, U.S. made steel rails approved for use by the Corps of Engineers are confined to the following types: For ordinary use, 85 -pound A.S.C.E. minimum; as an alternative, if economically justified, 90 -pound A.R.A.-A.; for heavier duty (on main lines and access or other tracks where the movement may be classified as "heavy" or where the desired speed exceeds 40 miles per hour), 115-pound A.R.E.A. sections. All such rails must conform to military specifications. Figure 75 shows cross sections of A.S.C.E. rails and of A.R.A. and A.R.E.A. rails and their characteristics.


Figure.75. • Dimensions and•properties of currently produced steel rails.
f. Steel Pipe.

| Nominal diameter (inches) | Dimensions |  |  |  |  |  | Couplings |  |  | Propertles |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Outside diameter (inches) | $\begin{aligned} & \text { Inside } \\ & \text { diameter } \\ & \text { (inches) } \end{aligned}$ | Thick-ness (inches) | Weight per foot-pound |  | $\begin{gathered} \text { Threads } \\ \text { per } \\ \text { inch } \end{gathered}$ | Outstie dameter (inches) | $\underset{\substack{\text { Length } \\ \text { (inch } \\ \text { es) }}}{ }$ | Welght(pounds) (pounds) | $\begin{gathered} \text { (inches) } \end{gathered}$ | $\underset{\text { (inches) }}{\mathbf{A}}$ | $\stackrel{r}{\text { (inches) }}$ |
|  |  |  |  | $\begin{aligned} & \text { Plain } \\ & \text { ends } \end{aligned}$ | Thread \& cplg. |  |  |  |  |  |  |  |
| STANDARD |  |  |  |  |  |  |  |  |  |  |  |  |
| 1/8. | 0. 405 | 0. 269 | 0.068 | 0. 24 | 0. 25 | 27 | 0. 562 | 7/8 | 0. 03 | 0.001 | 0. 072 | 0. 12 |
| 1/4 | 540 | . 364 | . 088 | . 42 | : 43 | 18 | . 685 | 1 | . 04 | . 003 | . 125 | . 16 |
| $3 / 8$ | . 675 | 493 | . 091 | 57 | 57 | 18 | . 848 | 11/8 | . 07 | 007 | . 167 | 21 |
| 1/2 | . 840 | . 622 | . 109 | . 85 | 85 | 14 | 1. 024 | 13/8 | . 12 | . 017 | 250 | 26 |
| $3 / 4$ | 1. 050 | 824 | 113 | 1. 13 | 1. 13 | 14 | 1. 281 | 158 | . 21 | . 037 | . 333 | . 33 |
| 1. | 1. 315 | 1. 049 | . 133 | 1. 68 | 1. 68 | $111 / 2$ | 1. 576 | 178 | $\therefore 35$ | . 087 | 494 | . 42 |
| 11/4- | 1. 660 | 1. 380 | . 140 | 2. 27 | 2. 28 | 111/2 | 1. 950 | $21 / 8$ | . 55 | . 195 | 669 | . 54 |
| 11/2 | 1. 900 | 1. 610 | . 145 | 2. 72 | 2. 73 | 11122 | 2. 218 | $23 / 8$ | . 76 | . 310 | 799 | . 62 |
| 2 | 2. 375 | 2. 067 | . 154 | 3. 65 | 3. 68 | 111/2 | 2. 760 | 2\% | 1. 23 | . 666 | 1. 075 | . 79 |
| 212 | 2. 875 | 2. 469 | . 203 | 5. 79 | 5. 82 | 8 | 3. 276 | 27/8 | 1. 76 | 1. 530 | 1. 704 | . 95 |
| 3. | 3. 500 | 3. 068 | . 216 | 7. 58 | 7. 62 | 8 | 3. 948 | $31 / 8$ | 2.55 | 3. 017 | 2. 228 | 1. 16 |
| $31 / 2$ | 4. 000 | 3. 548 | . 226 | 9. 11 | 9. 20 | 8 | 4. 591 | 358 | 4. 33 | 4. 788 | 2. 680 | 1. 34 |
| 4 | 4. 500 | 4. 026 | . 237 | 10. 79 | 10. 89 | 8 | 5. 091 | 35/8 | 5. 41 | 7. 233 | 3. 174 | 1. 51 |
| 5 | 5. 563 | 5. 047 | . 258 | 14. 62 | 14. 81 | 8 | 6. 296 | 418 | 9. 16 | 15. 16 | 4. 300 | 1. 88 |
| 6. | 6. 625 | 6. 065 | . 280 | 18. 97 | 19. 19 | 8 | 7. 358 | 41/8 | 10. 82 | 28. 14 | 5. 581 | 2. 25 |
| 8 | 8.625 | 8. 071 | . 277 | 24. 70 | 25. 00 | 8 | 9. 420 | 458 | 15. 84 | 63. 35 | 7. 265 | 2. 95 |
| 8 | 8. 625 | 7. 981 | . 322 | 28. 55 | 28. ${ }^{1} 81$ | 8 | 9. 420 | 458 | 15. 84 | 72. 49 | 8. 399 | 2. 94 |
| 10 | 10. 750 | 10. 192 | . 279 | 31. 20 | 32.00 | 8 | 11. 721 | 61/8 | 33. 92 | 125.9 | 9. 178 | 3. 70 |
| 10. | 10.750 | 10. 136 | . 307 | 34. 24 | 35. 00 | 8 | 11. 721 | 61/8 | 33. 92 | 137.4 | 10. 07 | 3. 69 |
| 10 | 10.750 | 10.020 | . 365 | 40. 48 | 41. 13 | 8 | 11. 721 | 61/8 | 33. 92 | 160. 7 | 11. 91 | 3. 67 |
| 12. | 12. 750 | 12.090 | . 330 | 43. 77 | 45.00 | 8 | 13. 958 | 61/8 | 48. 27 | 248. 5 | 12. 88 | 4. 39 |
| 12. | 12. 750 | 12.000 | . 375 | 49. 56 | 50.71 | 8 | 13. 958 | 61/8 | 48. 27 | 279. 3 | 14. 58 | 4. 38 |

EXtra strong

| 1/8- | 0. 405 | 0. 215 | 0. 095 | 0.31 | 0. 32 | 27 | 0. 582 | 11/8 | 0.05 | 0.001 | 0. 093 | $0.11{ }^{\text {- }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1/4. | 540 | . 302 | . 119 | . 54 | 54 | 18 | . 724 | $13 / 8$ | . 07 | . 004 | . 157 | 15 |
| 3/8. | 675 | 423 | 126 | 74 | 75 | 18 | . 898 | 158 | . 13 | . 009 | 217 | 20 |
| 120 | . 840 | 546 | 147 | 1. 09 | 1.10 | 14 | l. 085 | 178 | . 22 | 020 | 320 | 25 |
| $3 / 4$ | 1. 050 | 742 | . 154 | 1. 47 | 1. 49 | 14 | I. 316 | 21/8 | . 33 | 045 | 433 | 32 |
| 1 | 1. 315 | . 957 | . 179 | 2. 17 | 2. 20 | 11\% | I. 575 | $23 / 8$ | . 47 | . 106 | 639 | 41 |
| 11/4- | 1. 660 | 1. 278 | . 191 | 3. 00 | 3. 05 | 11\% | 2. 054 | 278 | 1. 04 | 242 | 881 | 52 |
| 11/2. | 1. 900 | 1. 500 | 200 | 3. 63 | 3. 69 | 11\% | 2. 294 | 278 | 1. 17 | 391 | 1. 068 | $61^{\prime}$ |
| 2 | 2. 375 | 1. 939 | 218 | 5. 02 | 5. 13 | 1112 | 2. 870 | 3\% | 2. 17 | 868 | 1. 477 | . 77 |
| 21/2 | 2. 875 | 2. 323 | 276 | 7. 66 | 7. 83 | 8 | 3. 389 | 41/8 | 3. 43 | 1. 924 | 2. 254 | . 92 |
| 3 | 3. 500 | 2. 900 | 300 | 10. 25 | 10. 46 | 8 | 4. 014 | 41/8 | 4.13 | 3. 894 | 3. 016 | 1. 14 |
| 31/2 | 4. 000 | 3. 364 | 318 | 12.51 | 12.82 | 8 | 4. 628 | 458 | 6. 29 | 6. 280 | 3. 678 | 1. 31 |
| 4 | 4. 500 | 3. 826 | . 337 | 14.98 | 15. 39 | 8 | 5. 233 | 458 | 8. 16 | 9. 610 | 4. 407 | 1. 48 |
| 5 | 5. 563 | 4. 813 . | . 375 | 20. 78 | 21. 42 | 8 | 6. 420 | 51/8 | 12. 87 | 20.67 | 6. 112 | 1. 84 |
| 6 | 6. 625 | 5. $761{ }^{\circ}$ | . 432 | 28. 57 | 29. 33 | 8 | 7. 482 | 51/8 | 15. 18 | 40. 49 | 8. 405 | 2. 20 |
| 8 | 8. 625 | 7. 625 | 500 | 43. 39 | 44. 72 | 8 | 9. 596 | 6\% | 26. 63 | 105. 7 | 12. 76 | 2. 88 |
| 10 | 10. 750 | 9. 750 | 500 | 54. 74 | 56. 94 | 8 | 11. 958 | 6\%\% | 44. 16 | 211. 9 | 16. 10 | 3. 53 |
| 12 | 12. 750 | 11. 750 | . 500 | 65. 42 | 68. 02 | 8 | 13. 958 | 658 | 51.99 | 361.5 | 19. 24 | 4. 34 |

Table 155. Steel Pipe—Continued

| Dintensions |  |  |  |  |  |  | Couplings |  |  | Propertles |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nominal diamcter (inches) | Outside diameter (inches) | $\begin{aligned} & \text { Inside } \\ & \text { diametcr } \\ & \text { (inches) } \end{aligned}$ | $\begin{aligned} & \text { Thlck- } \\ & \text { ness } \\ & \text { (inches) } \end{aligned}$ | Weight per foot-pound |  | Threads per inch | Outsidediametcr (inches) | Length (inches) | - Weight (pounds) | $\stackrel{\mathrm{I}}{\text { (Inches) }}$ | $\underset{\text { (inches) }}{\mathrm{A}}$ | $\underset{\text { (inches) }}{\mathrm{r}}$ |
|  |  |  |  | Plain ends | Threád \& cplg! |  |  |  |  |  |  |  |
| DOUBLE-EXTRA STRONG |  |  |  |  |  |  |  |  |  |  |  |  |
| 1/2 | 0. 840 | 0. 252 | 0. 294 | 1. 71 | 1. 73 | 14 | 1. 085 | 17/8 | 0. 22 | 0. 024 | 0. 504 | 0. 22 |
| 3/4 | 1. 050 | 434 | . 308 | 2. 44 | 2. 46 | 14 | 1. 316 | $21 / 8$ | . 33 | . 058 | . 718 | 28 |
| 1. | 1. 315 | . 599 | 358 | 3. 66 | 3. 68 | 111/2 | 1. 575 | $23 / 8$ | . 47 | . 140 | 1. 076 | 36 |
| $11 / 4$ | 1. 660 | 896 | 382 | 5. 21 | 5. 27 | 11122 | 2. 054 | $27 / 8$ | 1. 04 | . 341 | 1. 534 | . 47 |
| $11 / 2$ | 1. 900 | 1. 100 | . 400 | 6. 41 | 6. 47 | 1112 | 2. 294 | 27/8 | 1. 17 | . 568 | 1. 885 | . 55 |
| 2 | 2. 375 | 1. 503 | . 436 | 9. 03 | 9. 14 | 111/2 | 2. 870 | $35 / 8$ | 2. 17 | 1. 311 | 2. 656 | . 70 |
| 212. | 2. 875 | 1. 771 | . 552 | 13. 70 | 13. 87 | 8 | 3. 389 | 41/8 | 3. 43 | 2. 871 | 4. 028 | . 84 |
| 3. | 3. 500 | 2. 300 | . 600 | 18. 58 | 18. 79 | 8 | 4. 014 | 41/8 | 4. 13 | 5. 992 | 5. 466 | 1. 05 |
| 3112 | 4. 000 | 2. 728 | . 636 | 22. 85 | 23. 16 | 8 | 4. 628 | 4\%8 | 6. 29 | 9. 848 | 6. 721 | 1. 21 |
| 4 | 4. 500 | 3. 152 | . 674 | 27. 54 | 27. 95 | 8 | 5. 233 | - $45 \%$ | 8. 16 | 15. 28 | 8. 101 | 1. 37 |
| 5 | 5. 563 | 4. 063 | . 750 | 38. 55 | 39. 20 | 8 | 6. 420 | 51/8 | 12. 87 | 33.64 | 11. 34 | 1. 72 |
| 6 | 6. 625 | 4. 897 | . 864 | 53. 16 | 53. 92 | 8 | 7. 482 | 51/8 | 15. 18 | 66. 33 | 15. 64 | 2. 06 |
| 8. | 8. 625 | 6. 875 | . 875 | 72. 42 | 73. 76 | 8 | 9. 596 | 61/8 | 26. 63 | 162. 0 | 21. 30 | 2. 76 |

Pipe $14^{\prime \prime}$ and larger is sold by actual O.S. diameter and thickness.
Sizes, $14^{\prime \prime}, 15^{\prime \prime}$, and $16^{\prime \prime}$ are available regularly in thicknesses varying by $1 / 10^{\prime \prime}$ from $1 / 4^{\prime \prime}$ to $1^{\prime \prime}$, inclusive.
All pipe is furnished random length unless otherwise ordered, viz: 12 to 22 feet with privilege of furnishing 5 percent in 6 to 12 foot lengths. Pipe railing is most economically detailed with slip joints and random lengths between couplings.
152. Dimensions and Properties of Australian Beams


| $\begin{aligned} & \text { Ref. No. } \\ & \text { ASB- } \end{aligned}$ | Size | Weight for | Arca | Depth | Flange |  | Web thickness | Axis X-X |  |  | Axis $\mathrm{Y}-\mathrm{Y}$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Width | Thick- ness |  | I | S | r | I | S | r |
|  | Inches | pounds | Iuches | Inches | Inches | Inches | Inches | Inchcs | Inches | Inches | Inches | Inches | Inches |
|  | $3 \times 11 / 2$ | 4. 0 | 1. 18 | 3 | 11/2 | 0. 249 | 0. 16 | 1. 7 | 1. 1 | 1. 19 | 0.13 | 0. 17 | 0. 33 |
| 2 | $4 \times 3$ | 10.0 | 2. 94 | 4 | 3 | . 347 | . 24 | 7. 8 | 3. 9 | 1. 63 | 1. 32 | . 88 | . 67 |
| 3 | $41 / 2 \times 2$ | 7.0 | 2. 06 | 41/2 | 2 | . 322 | . 19 | 6. 7 | 3. 0 | 1. 80 | . 38 | . 38 | . 43 |
| 4 | $6 \times 3$ | 12.0 | 3. 53 | 6 | 3 | . 377 | 23 | 21. 0 | 7. 0 | 2. 44 | 1. 46 | . 97 | . 64 |
| 5 | $6 \times 5$ | 25.0 | 7. 35 | 6 | 5 | . 561 | . 33 | 45. 2 | 15. 1 | 2. 48 | 9. 87 | 3.95 | 1. 16 |
| 6 | $7 \times 31 / 2$ | 15.0 | 4. 42 | 7 | $31 / 2$ | . 398 | . 25 | 35.9 | 10. 3 | 2. 85 | 2. 41 | 1. 38 | . 7.4 |
|  | $8 \times 4$ | 18.0 | 5. 30 | 8 | 4 | . 398 | . 28 | 55.6 | 13.9 | 3. 24 | 3. 51 | 1. 75 | 81 |
| 8. | $8 \times 6$ | 35.0 | 10. 30 | 8 | 6 | . 648 | . 35 | 115. 1 | 28. 8 | 3. 34 | 19. 54 | 6.51 | 1. 38 |
| 9. | $9 \times 4$ | 21.0 | 6. 18 | 9 | 4 | . 457 | . 30 | 81.1 | 18.0 | 3. 62 | 4. 15 | 2. 07 | . 82 |
| 10 | $10 \times 41 / 2$ | 25.0 | 7. 35 | 10 | 41/2 | . 505 | . 30 | 122. 3 | 24.5 | 4. 08 | 6. 49 | 2. 88 | . 94 |
|  | $10 \times 6$ | 40.0 | 11. 77 | 10 | 6 | . 709 | . 36 | 204. 8 | 41.0 | 4. 17 | 21. 76 | 7. 25 | 1. 36 |
| 12 | . $10 \times 8$ | 55.0 | 16. 18 | 10 | 8 | . 783 | . 40 | 288.7 | 57.7 | 4. 22 | 54. 74 | 13.69 | 1. 84 |
| 13 | $12 \times 5$ | 30.0 | 8.83 | 12 | 5 | . 507 | . 33 | 206. 9 | 34.5 | 4. 84 | 8. 77 | 3. 51 | 1. 00 |
| 14 | $12 \times 8$ | 65.0 | 19. 12 | 12 | 8 | . 904 | . 43 | 487. 8 | 81. 3 | 5. 05 | 65. 18 | 16. 30 | 1. 85 |
| 15. | $13 \times 5$ | 35.0 | 10. 30 | 13 | 5 | . 604 | . 35 | 283. 5 | 43. 6 | 5. 25 | 10. 82 | 4.33 | 1. 03 |
| 16. | $14 \times 51 / 2$ | 40.0 | 11. 77 | 14 | 51/2 | . 627 | . 37 | 377.1 | 53.9 | 5. 66 | 14. 79 | 5. 38 | 1. 12 |
| 17 | $15 \times 6$ | 45. 0 | 13. 24 | 15 | 6 | . 655 | . 38 | 491. 9 | 65.6 | 6.09 | 19. 87 | 6. 62 | 1. 23 |
| 18. | $16 \times 6$ | 50.0 | 14. 71 | 16 | 6 | . 720 | . 40 | 618. 1 | 77. 3 | 6. 48 | 22. 47 | 7. 49 | 1. 24 |


| 19 | $16 \times 8$ | 75.0 | 22. 06 | 16 | 8 | 938 | . 48 | 973. 9 | 121. 7 | 6. 64 | 68. 30 | 17. 08 | 1. 76 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 20 | $18 \times 6$ | 55. 0 | 16. 18 | 18 | 6 | . 757 | . 42 | 841. 8 | 93. 5 | 7. 21 | 23. 64 | 7. 88 | 1. 21 |
| 21 | $20 \times 61 / 2$ | 65.0 | 19. 12 | 20 | 61/2 | . 820 | . 45 | 1226. 2 | 122.6 | 8.01 | 32. 56 | 10. 02 | 1. 31 |
| 22. | $22 \times 7$ | 75. 0 | 22. 06 | 22 | 7 | . 834 | . 50 | 1676. 8 | 152. 4 | 8. 72 | 41. 07 | 11. 73 | 1. 36 |
| 23 | $24 \times 7 / 2$ | 100. 0 | 29.39 | 24 | $71 / 2$ | 1. 070 | . 60 | 2654. 8 | 221. 2 | 9. 50 | 66. 87 | 17. 83 | 1. 51 |

153. Dimensions and Properties of Austrian and Danish Beams

Table 157. Austrian and Danish Bcams


| Number of profile | Depth in militmeters | Weight per | Area | Depth in inches | Flange |  | Web thickness | Axis $\mathrm{X}-\mathrm{X}$ |  |  | Axis $\mathrm{Y}-\mathrm{Y}$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Width | Thickness |  | I | S | r | I | S | r |
|  | Milli- <br> meters | Pounds | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Iuches | Inches | Inches |
| 8 | 80 | 4. 0 | 1. 17 | 3. 15 | 1. 654 | 0. 232 | 0. 154 | 1. 9 | 1. 2 | 1. 28 | 0. 15 | 0. 18 | 0. 36 |
| 9 | 90 | 4. 8 | 1. 40 | 3. 54 | 1. 811 | . 248 | . 165 | 2. 8 | 1. 6 | 1. 42 | . 21 | . 23 | . 39 |
| 10 | 100 | 5. 6 | 1. 64 | 3.94 | 1. 969 | 268 | 177 | 4. 1 | 2. 1 | 1. 58 | . 29 | 30 | . 41 |
| 11 | 110 | 6. 5 | 1. 91 | 4. 33 | 2. 126 | 283 | . 189 | 5. 7 | 2. 7 | 1. 73 | . 39 | . 37 | . 45 |
| 12 | 120 | 7. 5 | 2. 20 | 4. 72 | 2. 283 | . 303 | 201 | 7.9 | 3.3 | 1. 89 | . 52 | . 45 | . 48 |
| 13 | 130 | 8. 5 | 2. 50 | 5. 12 | 2. 441 | . 319 | 213 | 10.5 | 4. 1 | 2. 04 | . 66 | . 54 | 52 |
| 14 | 140 | 9. 7 | 2. 84 | 5.51 | 2. 598 | . 339 | . 224 | 13.8 | 5. 0 | 2. 24 | . 84 | . 65 | 55 |
| 15 | 150 | 10.8 | 3. 16 | 5. 90 | 2. 756 | . 354 | . 236 | 17. 7 | 6. 0 | 2. 36 | 1. 05 | 76 | 57 |
| 16 | 160 | 12. 0 | 3. 53 | 6. 30 | 2. 913 | . 374 | . 248 | 22.5 | 7. 1 | 2. 52 | 1. 31 | . 90 | . 61 |
| 17 | 170 | 13. 3 | 3. 91 | 6. 69 | 3. 071 | . 390 | 260 | 28.0 | 8. 3 | 2. 68 | 1. 60 | 1. 04 | 64 |
| 18. | 180 | 14. 7 | 4. 32 | 7. 09 | 3. 228 | . 409 | . 272 | 34.8 | 9. 8 | 2. 83 | 1.95 | 1. 21. | 67 |
| 19 | 190 | 16. 1 | 4. 73 | 7. 48 | 3. 386 | . 425 | . 283 | 42. 3 | 11. 3 | 2. 99 | 2. 34 | 1. 39 | 71 |
| 20. | 200 | 17. 7 | 5. 19 | 7. 87 | 3. 543 | . 445 | . 295 | 51.4 | 13.0 | 3. 15 | 2. 81 | 1. 59 | . 74 |
| 21 | 210 | 19.2 | 5. 63 | 8. 27 | 3. 700 | . 460 | . 307 | 61.6 | 14.9 | 3. 31 | 3. 31 | 1. 79 | . 77 |
| 22 | 220 | 20.9 | 6. 14 | 8. 66 | 3. 858 | . 480 | . 319 | 73. 5 | 17.0 | 3. 46 | 3. 89 | 2. 01 | 80 |
| 23. | 230 | 22. 5 | 6. 62 | 9. 06 | 4. 016 | . 496 | . 331 | 86.6 | 19.2 | 3. 62 | 4. 54 | 2. 26 | . 83 |
| 24. | 240 | 24.3 | 7. 14 | 9. 45 | 4. 173 | . 516 | . 343 | 102. 1 | 21.6 | 3. 78 | 5. 31 | 2. 54 | . 86 |


| 25. | 250 | 26． 2 | 7． 70 | 9． 84 | 4． 331 | 535 | ． 354 | 119.3 | 24． 2 | 3． 94 | 6． 15 | 2． 83 | ． 89 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 26 | 260 | 28.2 | 8． 28 | 10． 24 | 4． 449 | 555 | 370 | 137． 9 | 27． 0 | 4． 09 | 6． 92 | 3． 11 | 91 |
| 27 | 270 | 30.2 | 8． 87 | 10． 63 | 4． 567 | 579 | 382 | 159.2 | 30.0 | 4． 21 | 7． 83 | 3． 43 | ． 94 |
| 28 | 280 | 32.3 | 9． 47 | 11． 02 | 4． 685 | 598 | 398 | 182． 3 | 33.1 | 4． 37 | 8． 74 | 3． 73 | 96 |
| 29 | 290 | 34.2 | 10． 05 | 11． 42 | 4． 803 | ． 618 | 409 | 207． 4 | 36． 4 | 4.53 | 9． 75 | 4． 06 | ． 99 |
| 30 | 300 | 36． 4 | 10． 70 | 11． 81 | 4． 921 | 638 | ． 425 | 235． 4 | 39.8 | 4． 68 | 10． 83 | 4． 41 | 1． 01 |
| 32 | 320 | 41． 1 | 12． 05 | 12． 60 | 5． 157 | ． 681 | ： 453 | 300． 5 | 47． 7 | 5． 00 | 13． 33 | 5． 17 | 1． 05 |
| 34 | 340 | 45． 8 | 13． 45 | 13． 39 | 5． 394 | 720 | ． 480 | 377.1 | 56． 3 | 5． 28 | 16． 19 | 6． 00 | 1． 10 |
| 36 | 360 | 51． 2 | 15． 04 | 14.17 | 5． 630 | ． 768 | 512 | 471.0 | 66． 5 | 5． 58 | 19．65 | 6.96 | 1． 14 |
| 38 | 380 | 56.4 | 16． 57 | 14． 96 | 5． 866 | 807 | 539 | 576.7 | 76． 9 | 5． 89 | 23． 42 | 7.99 | 1． 19 |
| 40 | 400 | 62． 2 | 18． 28 | 15． 75 | 6． 102 | ． 850 | ． 567 | 701． 6 | 89． 1 | 6． 19 | 27． 82 | 9． 09 | 1． 23 |
| 421／2 | 425 | 69.9 | 20.45 | 16． 73 | 6． 417 | 906 | 602 | 888.0 | 106． 1 | 6． 58 | 34． 52 | 10． 74 | 1． 30 |
| 45 | 450 | 77.3 | 22． 77 | 17． 72 | 6． 693 | ． 957 | ． 638 | 1，101． 4 | 124． 5 | 6． 95 | 41． 43 | 12． 39 | 1． 35 |
| 47／2 | 475 | 86.0 | 25． 25 | 18． 70 | 7． 008 | 1． 008 | 673 | 1， 356.7 | 145． 2 | 7． 32 | 50． 15 | 14． 34 | 1． 41 |
| 50 | 500 | 94． 8 | 27． 88 | 19．69 | 7． 283 | 1． 063 | 708 | 1，651． 1 | 167． 8 | 7． 69 | 59． 52 | 16． 35 | 1． 46 |
| 55 | 550 | 112． 2 | 32． 99 | 21． 65 | 7． 874 | 1． 181 | 748 | 2， 382.4 | 220． 3 | 8． 49 | 83． 78 | 21． 30 | 1． 59 |



| Reference mark | Weight per foot | Area | Depth | Flange |  | $\begin{aligned} & \text { Web } \\ & \text { thickness } \end{aligned}$ | Axis $\mathrm{X}-\mathrm{X}$ |  |  | Axis Y-Y |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Width | Thickness |  | I | S | r | I | S | r |
|  | Pounds | Inches | Inches | Inches | Inches | Inch | Inchey | Inches | Inches | Inches | Inches | Inches |
| BSB 140 | 95 | 27. 94 | 24 | 71/2 | 1. 011 | 0. 57 | 2, 290 | 190.8 | 9.52 | 62.5 | 16. 7 | 1. 5 |
| 139 | 75 | 22. 06 | 22 | 7 | . 834 | . 50 | 1, 505 | 136. 8 | 8. 72 | 41.1 | 11. 7 | 1. 4 |
| 138 | 89 | 26. 19 | 20 | 71/2 | 1. 010 | . 60 | 1, 507 | 150.7 | 7. 99 | 62.5 | 16. 7 | 1. 6 |
| 137 | 65 | 19. 12 | 20 | 61/2 | . 820 | . 45 | 1, 088 | 108. 8 | 8.01 | 32. 6 | 10: 0 | 1. 3 |
| 136 | 80 | 23. 53 | 18 | 8 | . 950 | . 50 | 1,167 | 129. 7 | 7. 41 | 69.4 | 17. 4 | 1. 7 |
| 135 | 75 | 22.09 | 18 | 7 | . 928 | . 55 | 1, 026 | 114.0 | 7. 22 | 46. 6 | 13. 3 | 1. 5 |
| 134 | 55 | 16.18 | 18. | 6 | . 757 | . 12 | 752 | 83.6 | 7. 21 | 23.6 | 7. 9 | 1. 2 |
| 133 | 75 | 22. 06 | 16 | 8 | . 938 | . 48 | 878 | 109.8 | 6. 64 | 68.3 | 17. 1 | 1. 8 |
| 132 | 62 | 18. 21 | 16 | 6 | . 847 | . 55 | 647 | 80.9 | 6.31 | 27. 1 | 9.1 | 1.2 |
| 131 | 50 | 14. 71 | 16 | 6 | . 726 | . 40 | 551 | 68.9 | 6. 48 | 22.5 | 7. 5 | 1. 2 |
| 130 | 45 | 13. 24 | 15 | 6 | . 655 | . 38 | 439 | 58.5 | 6. 10 | 19.9 | 6. 6 | 1. 2 |
| 129 | 42 | 12. 36 | 15 | 5 | . 647 | . 42 | 375 | 50.0 | 5. 89 | 11.8 | 4. 7 | 1. 0 |
| 128 | 70 | 20.59 | 14 | 8 | . 920 | . 46 | 634 | 90.6 | 5. 85 | 66. 7 | 16. 7 | 1. 8 |
| 127 | 57 | 16. 78 | 14 | 6 | . 873 | 50 | 473 | 67.6 | 5. 64 | 27. 9 | 9.3 | 1. 3 |
| 126 | 46 | 13.59 | 14 | 6 | . 698 | 40 | 394 | 56.3 | 5. 71 | 21.5 | 7. 2 | 1. 3 |
| 125 | 35 | 10. 30 | 13 | 5 | . 604 | . 35 | 246 | 37. 8 | 5. 25 | 10. 8 | 4. 3 | 1. $\dot{0}$ |
| 124. | 65 | 19. 12 | 12 | 8 | . 904 | . 43 | 437 | 72. 8 | 5. 05 | 65. 2 | 16. 3 | 1. 9 |
| 123. | 54 | 15. 89 | 12 | 6 | . 883 | . 50 | 332 | 55. 3 | 4. 86 | 28. 3 | 9.4 | 1. 3 |



## 155. Dimensions and Properties of German Beams

Table 159. German Wide-Flange Beams


| Nominal size (depthin cemtimeters) | Weight per foot | Area | Depth | Flange |  | $\underset{\text { Web }}{\substack{\text { Whickness }}}$ | Axis $U-U$ |  |  | Axis $\mathrm{Y}-\mathrm{Y}$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Width | Thickness |  | I | S | r | I | S | r |
|  | Pounds | Inches | Inches | Inches | Inches | Inch | Iuches | Iuches | Inches | Inches | Inches | Inchcs |
| 10. | 14 | 4. 05 | 3. 94 | 3. 937 | 0. 393 | 0. 256 | 10. 7 | 5. 4 | 1. 63 | 4. 0 | 2. 0 | 1. 00 |
| 12 | 18 | 5. 32 | 4. 72 | 4. 724 | . 433 | 276 | 20.8 | 8. 8 | 1. 98 | 7. 6 | 3.2 | 1. 20 |
| 14 | 23 | 6. 84 | 5. 51 | 5. 512 | . 472 | 315 | 36. 5 | 13. 2 | 2. 31 | 13. 2 | 4. 8 | 1. 39 |
| 16. | 31 | 9. 05 | 6. 30 | 6. 299 | . 551 | 354 | 63.2 | 20. 1 | 2. 65 | 23. 0 | 7. 3 | 1. 59 |
| 18. | 35 | 10. 20 | 7. 09 | 7. 087 | . 551 | . 354 | 92.0 | 26. 0 | 3. 00 | 32.7 | 9. 2 | 1. 79 |
| 20. | 44 | 12. 82 | 7. 87 | 7. 874 | . 630 | . 394 | 142. 9 | 36. 3 | 3. 34 | 51.4 | 13. 1 | 2. 00 |
| 22 | 48 | 14. 12 | 8. 66 | 8. 661 | . 630 | . 394 | 193. 4 | 44. 7 | 3. 69 | 68.2 | 15. 7 | 2. 20 |
| 24. | 59 | 17. 20 | 9. 44 | 9. 449 | . 709 | . 433 | 280.9 | 59. 4 | 4. 06 | 99.7 | 21. 1 | 2. 41 |
| 26. | 64 | 18. 75 | 10. 24 | 10. 236 | 709 | . 433 | 361.6 | 70. 8 | 4. 41 | 126.8 | 24. 9 | 2. 60 |
| 28. | 76 | 22. 32 | 11. 02 | 11. 024 | 787 | . 472 | 497.8 | 90.3 | 4. 72 | 175. 8 | 32. 0 | 2. 81 |
| 30. | 81 | 23. 87 | 11. 81 | 11. 811 | 787 | 472 | 618.9 | 105. 0 | 5. 08 | 216. 4 | 36. 7 | 3. 01 |
| 32. | 91 | 26. 50 | 12. 60 | 11.811 | 866 | 512 | 774.8 | 123. 3 | 5. 39 | 238. 0 | 40. 4 | 2. 99 |
| 34. | 92 | 26. 97 | 13. 39 | 11.811 | 866 | . 512 | 887.5 | 132. 4 | 5. 71 | 238.0 | 40. 4 | 2. 97 |
| 36. | 101 | 29. 76 | 14.17 | 11. 811 | . 945 | . 551 | 1084. 0 | 153.2 | 6. 02 | 259.7 | 44. 1 | 2. 96 |
| 38. | 103 | 30. 07 | 14. 96 | 11. 811 | . 945 | . 551 | 1224. 1 | 163. 6 | 6. 38 | 259.7 | 44. 1 | 2. 94 |
| 40. | 110 | 32. 39 | 15. 75 | 11. 811 | 1. 024 | . 551 | 1456. 9 | 185. 0 | 6. 69 | 281. 3 | 47. 8 | 2. 95 |
| 421/2---------- | 112 | 32. 86 | 16. 73 | 11. 811 | 1. 024 | . 551 | 1669. 3 | 199. 5 | 7. 13 | 281. 3 | 47. 8 | 2. 93 |
| 45 | 122 | 35. 96 | 17. 72 | 11. 811 | 1. 102 | . 591 | 2023. 4 | 228. 2 | 7. 48 | 303. 1 | 51. 4 | 2. 91 |



Table 160. German I-Beams


| Nominal size (depth in centimeters) | Weight per foot | Area | Depth | Flange |  | $\begin{aligned} & \text { Wcb } \\ & \text { thick ness } \end{aligned}$ | Axis X -X |  |  | Axis Y-Y |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Width | 'Ihickness |  | I | S | r | I | S | r |
|  | Pounds | Iuches | Iuches: | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches |
| 8 | 4 | 1. 17 | 3. 15 | 1. 654 | 0.232 | 0. 154 | 1. 9 | 1. 3 | 1. 26 | 0. 2 | 0.2 | 0. 36 |
| 10 | 6 | 1. 64 | 3. 94 | 1. 969 | . 268 | . 177 | 4. 1 | 2. 2 | 1. 58 | 3 | . 3 | . 42 |
| 12 | 8 | 2. 20 | 4. 72 | 2. 283 | 303 | . 201 | 7. 9 | 3. 3 | 1. 89 | . 5 | . 5 | . 48 |
| 14 | 10 | 2. 84 | 5. 51 | 2. 598 | . 339 | . 224 | 13.8 | 5. 0 | 2.01 | . 8 | . 7 | . 55 |
| 16 | 12 | 3. 53 | 6. 30 | 2. 913 | . 374 | . 248 | 22.5 | 7. 2 | 2. 52 | 1. 3 | 1.0 | . 61 |
| 18 | 15 | 4. 32 | 7. 09 | 3. 228 | 409 | 272 | 34.8 | 9. 8 | 2. 83 | 2. 0 | 1. 3 | . 67 |
| . 20 | 18 | 5. 19 | 7. 87 | 3. 543 | . 445 | 295 | 51.4 | 13.1 | 3. 15 | 2. 8 | 1. 7 | . 74 |
| 22 | 21 | 6. 14 | 8. 66 | 3. 858 | . 480 | 319 | 73. 5 | 17. 0 | 3. 46 | 3. 9 | 2. 1 | . 80 |
| 24 | 24 | 7. 15 | 9. 45 | 4. 173 | . 516 | 343 | 102. 1 | 21. 6 | 3. 78 | 5. 3 | 2. 5 | . 87 |
|  | 28 | 8. 28 | 10. 24 | 4. 449 | 555 | 370 | 137. 9 | 27. 0 | 4. 09 | 6. 9 | 3. 1 | . 91 |
| 28 | 32 | 9. 47 | 11. 02 | 4. 685 | 598 | 398 | 182. 3 | 33.1 | 4. 37 | 8. 7 | 3. 7 | . 96 |
| 30 | 36 | 10. 71 | 11. 81 | 4. 921 | . 638 | . 425 | 235. 4 | 39.8 | 4. 69 | 10.8 | 4. 4 | 1. 01 |
| 32 | 41 | 12. 06 | 12. 60 | 5. 157 | . 681 | . 453 | 300.6 | 47. 7 | 5. 00 | 13. 3 | 5. 2 | 1. 05 |
| 34 | 46 | 13. 45 | 13. 39 | .5. 394 | . 720 | . 480 | 377.2 | 56. 3 | 5. 31 | 16. 2 | 6. 0 | 1. 10 |
| 36. | 51 | 15. 05 | 14. 17 | 5. 630 | . 768 | . 512 | 471. 1 | 66.5 | 5. 59 | 19. 6 | 7. 0 | 1. 14 |
| 38. | 56 | 16. 58 | 14. 96 | 5. 866 | . 807 | . 539 | 576.8 | 76. 9 | 5. 91 | 23. 4 | 8. 0 | 1. 19 |
| 40 | 62 | 18. 29 | 15. 75 | 6. 102 | . 850 | . 567 | 701. 8 | 89. 1 | 6. 18 | 27. 9 | 9. 1 | 1. 23 |
| $421 / 2$ | 70 | 20. 46 | 16. 73 | 6. 417 | . 906 | . 602 | 888. 2 | 106. 2 | 6. 57 | 34. 6 | 10. 7 | 1. 30 |


| 45. | 77 | 22. 79 | 17. 72 | 6. 693 | . 957 | . 638 | 1, 101. 5 | 124. 5 | 6. 97 | 41. 6 | 12. 4 | 1. 35 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 471/2 | 86 | 25. 27 | 18.70 | 7. 008 | 1. 008 | . 673 | 1, 356. 9 | 145. 2 | 7. 32 | 50.2 | 14.3 | 1. 42 |
| 50 | 95 | 27. 90 | 19.69 | 7. 283 | 1. 063 | 709 | 1,651. 5 | 167.8 | 7. 72 | 59.6 | 16. 4 | 1. 46 |
| 55. | 112 | 33. 02 | 21. 65 | 7. 874 | 1. 181 | . 748 | 2, 382.8 | 220. 3 | 8. 50 | 83.8 | 21. 3 | 1. 58 |
| 60 | 134 | 39. 37 | 23. 62 | 8. 465 | 1. 276 | . 850 | 3, 339. 5 | 282.5 | 9. 21 | 112.2 | 26. 5 | 1. 69 |

156. Dimensions and Properties of Indian I-Beams

Table 161. Indian I-Beams


| Ref No. BSB-- | Size | $\begin{gathered} \text { Weight } \\ \text { per } \\ \text { foot } \end{gathered}$ | Area | Depth | Flange |  | Web thick ness | Axis X-X |  |  | Axis Y-Y |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Width | Thick- |  | 1 | S | r | I | S | r |
|  | Inches | Pounds | Inches | Inches | Inches | Inches | Inches | Iuches | Inches | Inches | Inches | Jnches | Inches |
| 101 | $3 \times 11 / 2$ | 4. 0 | 1. 18 | 3 | 11/2 | 0. 249 | 0. 160 | 1. 7 | 1. 1 | 1. 19 | . 13 | 0. 17 | 0.32 |
| 103 | $4 \times 13 / 4$ | 5. 0 | 1. 47 | 4 | $13 / 4$ | . 239 | . 170 | 3. 7 | 1. 8 | 1. 58 | . 19 | . 21 | . 36 |
| 105 | $43 / 4 \times 13 / 4$ | 6. 5 | 1. 91 | $43 / 4$ | $13 / 4$ | . 325 | . 180 | 6. 7 | 2. 8 | 1. 88 | . 26 | . 30 | . 37 |
| 4. | $4 \times 3$ | 9. 5 | 2. 79 | 4 | 3 | . 336 | . 220 | 7.5 | 3. 8 | 1. 64 | 1. 28 | . 85 | . 68 |
| 104 | $4 \times 3$ | 10.0 | 2. 94 | 4 | 3 | . 347 | 240 | 7. 8 | 3. 9 | 1. 63 | 1. 33 | . 88 | . 67 |
| 6 | $5 \times 3$ | 11. 0 | 3. 24 | 5 | 3 | . 376 | 220 | 13. 7 | 5. 5 | 2.05 | 1. 45 | . 97 | . 67 |
| 7 | $5 \times 41 / 2$ | 18.0 | 5. 29 | 5 | 41/2 | . 448 | . 290 | 22.7 | 9.1 | 2.07 | 5. 66 | 2. 52 | 1. 03 |
| 108 | $6 \times 3$ | 12.0 | 3. 53 | 6 | 3 | . 377 | . 230 | 21.0 | 7.0 | 2. 44 | 1. 46 | . 97 | . 64 |
| 110 | $6 \times 5$ | 25. 0 | 7. 37 | 6 | 5 | . 520 | . 410 | 43. 7 | 14. 6 | 2. 44 | 9. 10 | 3. 64 | 1. 11 |
| 11 | $7 \times 4$ | 16. 0 | 4. 71 | 7 | 4 | . 387 | . 250 | 39.5 | 11.3 | 2. 89 | 3.37 | 1. 69 | 84 |
| 112 | $8 \times 4$ | 18.0 | 5. 30 | 8 | 4 | . 398 | . 280 | 55.6 | 13.9 | 3. 24 | 3.51 | 1. 75 | . 81 |
| 113 | $8 \times 5$ | 28.0 | 8. 28 | 8 | 5 | . 575 | . 350 | 89.7 | 22.4 | 3. 29 | 10. 19 | 4. 08 | 1. 11 |
| 114 | $8 \times 6$ | 35.0 | 10.30 | 8 | 6 | . 648 | . 350 | 115. 1 | 28.8 | 3. 34 | 19. 54 | 6.51 | 1. 38 |
| 117. | $10 \times 41 / 2$ | 25. 0 | 7. 35 | 10 | 41/2 | . 505 | . 300 | 122. 3 | 24.5 | 4. 08 | 6. 49 | 2. 88 | :.94 |
| 20. | $12 \times 5$ | 32.0 | 9. 41 | 12 | 5 | . 550 | . 350 | 192. 0 | 36.8 | 4. 84 | 9. 69 | 3. 88 | 1. 01 |
| 21 | $12 \times 6$ | 44. 0 | 12. 95 | 12 | 6 | . 717 | . 400 | 281.0 | 52.8 | 4. 94 | 22. 12 | 7. 37 | 1. 30 |
|  | $12 \times 6$ | 54.0 | 15. 88 | 12 | 6 | . 717 | . 625 |  |  |  |  |  |  |


| 125 | $13 \times 5$ | 35. 0 | 10. 30 | 13 | 5 | 604 | . 350 | 246. 0 | 43. 6 | 5. 25 | 10. 82 | 4. 33 | 1. 03 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 25 | $15 \times 5$ | 42. 0 | 12. 35 | 15 | 5 | . 647 | . 420 | 375.0 | 57. 1 | 5. 89 | 11.81 | 4. 72 | . 98 |
| 26 | $15 \times 6$ | 59.0 | 17. 35 | 15 | 6 | 880 | . 500 | 559.0 | 83.9 | 6. 02 | 28. 22 | 9.41 | 1. 27 |
| 130 | $16 \times 6$ | 45.0 | 13. 24 | 16 | 6 | 665 | . 380 | 439.0 | 65. 6 | 6. 09 | 19.87 | 6. 62 | 1, 23 |
| 131 | $18 \times 6$ | 50.0 | 14. 71 | 18 | 6 | . 726 | . 400 | 551.0 | .77. 3 | 6. 48 | 22. 47 | 7. 49 | 1. 24 |
| 134 | $18 \times 6$ | 55.0 | 16. 18 | 18 | 6 | . 757 | . 420 | 752.0 | 93. 5 | 7. 21 | 23. 63 | 7. 88 | 1. 21 |
| 137 | $20 \times 61 / 2$ | 65.0 | 19. 12 | 20 | 61/2 | . 820 | 450 | 1088. 0 | 122.6 | 8. 01 | 32. 56 | 10. 02 | 1. 31 |
| 139 | $22 \times 7$ | 75.0 | 22. 06 | 22 | 7 | . 834 | 500 | 1505. 0 | 152. 4 | 8. 72 | 41. 07 | 11. 73 | 1. 36 |
| NBSB |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 | $7 \times 31 / 2$ | 15.0 | 4. 42 | 7 | $31 / 2$ | . 398 | . 250 | 35. 9 | 10.3 | 2. 85 | 2. 41 | 1. 38 | 74 |
| 8. | $9 \times 4$ | 21.0 | 6. 18 | 9 | 4 | . 460 | . 300 | 81. 1 | 18. 0 | 3. 62 | 4. 15 | 2. 07 | : 82 |
| 17 | $10 \times 5$ | 30.0 | 8.82 | 10 | 5 | . 552 | . 360 | 127.0 | 29. 3 | 4. 06 | 9. 73 | 3. 89 | 1: 05 |
| 10 | $12 \times 5$ | 30.0 | 8. 82 | 12 | 5 | . 507 | . 330 | 180. 0 | 34. 5 | 4. 84 | 8. 77 | 3: 51 | 1: 00 |
| 18. | $24 \times 71 / 2$ | 90.0 | 26. 47 | 24 | 71/2 | . 984 | 520 |  |  |  |  |  |  |
|  | $24 \times 71 / 2$ | 95.0 | 27. 91 | 24 | 71/2 | . 984 | . 578 |  |  |  |  |  |  |
|  | $24 \times 71 / 2$ | 100.0 | 29.40 | 24 | 71/2 | . 984 | . 625 |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

## 157. Dimensions and Properties of Italian I-Beams

Table 162. Italian I-Beams


| Profile | Depth in mlllimeters | Weight fer foot | Area | $\begin{aligned} & \text { Depth } \\ & \text { in } \\ & \text { Inches } \end{aligned}$ | Flunge |  | Wel, thickness | Axis $\mathrm{X}-\mathrm{X}$ |  |  | AxIs Y-Y |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Wrdth | Thickness |  | I | S | r | I | S | r |
|  | Millimeters | Pounds | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches | Inches |
| 80 | 80 | 4. 0 | 1. 18 | 3. 15 | 1. 654 | 0. 232 | 0. 154 | 1. 9 | 1. 2 | 1. 28 | 0. 15 | 0. 18 | 0. 36 |
| 100 | 100 | 5.6 | 1. 64 | 3. 94 | 1. 969 | . 268 | . 177 | 4. 1 | 2. 1 | 1. 58 | . 29 | . 30 | . 42 |
| 120 | 120 | 7. 5 | 2. 20 | 4. 72 | 2. 283 | . 303 | . 200 | 7.9 | 3.3 | 1. 89 | . 51 | . 45 | . 48 |
| 140 | 140 | 9. 7 | 2. 84 | 5. 51 | 2. 598 | . 339 | . 224 | 13. 7 | 5. 0 | 2. 20 | . 84 | . 65 | . 55 |
| 160 | 160 | 12.0 | 3. 54 | 6. 30 | 2. 913 | . 374 | . 248 | 22. 4 | 7. 1 | 2. 52 | 1. 31 | . 90 | . 61 |
| 180 | 180 | 14. 7 | 4. 32 | 7. 09 | 3. 228 | . 409 | . 272 | 34.7 | 9.8 | 2. 83 | 1. 95 | 1. 21 | . 67 |
| 200 | 200 | 17. 7 | 5. 20 | 7. 88 | 3. 543 | . 445 | . 295 | 51. 4 | 13. 1 | 3. 15 | 2. 78 | 1. 58 | . 74 |
| 220 | 220 | 21. 4 | 6. 14 | 8. 66 | 3. 858 | . 481 | . 319 | 73. 5 | 17. 0 | 3. 46 | 3. 89 | 2.02 | . 80 |
| 240 | 240 | 24.3 | 7. 14 | 9. 45 | 4. 173 | . 516 | . 343 | 102. 1 | 21. 6 | 3. 78 | 5. 28 | 2. 53 | . 86 |
| 250 | 250 | 26.1 | 7. 67 | 9. 85 | 4. 331 | . 535 | . 354 | 119. 3 | 22.8 | 3. 93 | 6.13 | 2.83 | . 89 |
| 260 | 260 | 28. 2 | 8. 29 | 10. 25 | 4. 449 | . 556 | . 370 | 137. 9 | 27.0 | 4. 09 | 6. 89 | 3.11 | . 91 |
| 280 | 280 | 32.2 | 9.47 | 11. 02 | 4. 685 | . 599 | . 398 | 182. 3 | 33.1 | 4. 37 | 7. 19 | 3. 72 | . 96 |
| 300 | 300 | 36. 4 | 10. 70 | 11. 81 | 4. 921 | . 638 | . 425 | 235.4 | 39.8 | 4. 69 | 10.83 | 4. 39 | 1. 00 |
| 320 | 320 | 41. 0 | 12. 05 | 12. 60 | 5. 157 | . 681 | . 453 | 300.5 | 47.7 | 5. 00 | 13. 33 | 5. 16 | 1. 05 |
| 340 | 340 | 45.7 | 13. 45 | 13. 39 | 5. 394 | . 721 | . 480 | 377.1 | 56. 3 | 5. 31 | 16. 19 | 5. 99 | 1. 10 |
| 360 | 360 | 51. 2 | 15. 04 | 14. 17 | 5. 630 | . 767 | . 519 | 471. 0 | 66.5 | 5. 59 | 19.65 | 6. 95 | 1. 14 |


| 380 | 380 | 56.4 | 16． 57 | 14． 96 | 5． 866 | ． 807 | ． 539 | 576． 7 | 76． 9 | 5． 91 | 23． 42 | 7.00 | 1． 19 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 400. | 400 | 62.2 | 18． 28 | 15． 75 | 6． 102 | ． 851 | ． 567 | 701． 6 | 89.1 | 6． 18 | 27． 82 | 9.09 | 1． 23 |
| 425 | 425 | 69.9 | 20． 45 | 16． 73 | 6． 417 | ． 905 | ． 602 | 888.0 | 106． 1 | 6． 57 | 34． 52 | 10． 74 | 1． 30 |
| 450. | 450 | 77． 5 | 22． 77 | 17． 72 | 6． 693 | ． 958 | ． 638 | 1，101． 4 | 124． 5 | 6． 97 | 41． 43 | 12． 39 | 1． 35 |
| 475. | 475 | 86.0 | 25． 25 | 18．70 | 7． 008 | 1． 008 | ． 673 | 1， 356.7 | 144． 9 | 7． 32 | 50． 15 | 14． 28 | 1． 41 |
| 500 | 500 | 94.9 | 27． 88 | 19． 69 | 7． 283 | 1． 063 | ． 709 | 1，651． 1 | 167． 8 | 7． 72 | 59． 52 | 16． 35 | 1． 46 |
| 550 | 550 | 112． 5 | 32． 99 | 21． 65 | 7． 874 | 1． 181 | ． 748 ． | 2， 382.4 | 220.3 | 8.50 | 83． 78 | 21． 23 | 1． 58 |
| 600. | 600 | 133． 7 | 39． 37 | 23． 62 | 8． 464 | 1． 276 | ． 850 | 3，334． 2 | 282． 2 | 9． 21 | 112． 39 | 26． 54 | 1． 69 |

158. Dimensions and Properties of Portuguese I-Beams

Table 163. Portuguese I-Beams


| Scetion | $\begin{gathered} \text { beptlı } \\ \text { in } \\ \text { milli- } \\ \text { moters } \end{gathered}$ | Weight per foot | Arch | $\begin{aligned} & \text { Deptht } \\ & \text { inches } \\ & \text { inch } \end{aligned}$ | Flange |  | Web thickness | Axis $\mathrm{X}-\mathrm{X}$ |  |  | Axis $\mathrm{Y}-\mathrm{Y}$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Width | Thnekness |  | I | S | ${ }^{1}$ | I | S | r |
|  | Millimelers | Pounds | Inches | Inchcs | Inches | Inches | Iuches | Inches | Inches | Iuches | Inches | Inches | Inchcs |
| 10. | 100 | 13.8 | 4. 05 | 3. 94 | 3. 937 | 0. 394 | 0. 256 | 10. 7 | 5. 5 | 1. 63 | 4. 0 | 2. 0 | 1. 00 |
| 12 | 120 | 18. 1 | 5. 32 | 4. 72 | 4. 724 | . 433 | 276 | 20.8 | 8. 8 | 1. 98 | 7. 6 | 3. 2 | 1. 20 |
| 14. | 140 | 23.3 | 6. 84 | 5. 51 | 5. 512 | 472 | 315 | 36.5 | 13. 2 | 2. 31 | 13. 2 | 4. 8 | 1. 39 |
| 16 | 160 | 30. 1 | 9. 05 | 6. 30 | 6. 299 | 551 | 354 | 63.2 | 20. 1 | 2. 65 | 23. 0 | 7. 3 | 1. 59 |
| 18. | 180 | 34. 7 | 10.20 | 7. 09 | 7. 086 | 551 | 354 | 92. 0 | 26. 0 | 3. 00 | 32. 7 | 9. 2 | 1. 79 |
| 20 | 200 | 43.6 | 12. 82 | 7. 88 | 7. 874 | . 630 | 394 | 142.9 | 36.3 | 3. 34 | 51.4 | 13.1 | 2. 00 |
| 22 | 220 | 48.0 | 14. 12 | 8. 66 | 8. 661 | 630 | 394 | 193. 4 | 44. 7 | 3. 69 | 68. 2 | 15. 7 | 2. 20 |
| 24 | 240 | 58.7 | 17. 21 | 9. 45 | 9. 449 | 709 | 433 | 280.8 | 59.4 | 4. 13 | 99. 7 | 21.1 | 2. 41 |
| 26 | 260 | 63.7 | 18. 76 | 10. 24 | 10. 236 | 709 | . 433 | 361. 5 | 70.8 | 4. 41 | 126. 8 | 24. 8 | 2. 60 |
| 28 | 280 | 75. 9 | 22. 32 | 11. 02 | 11. 024 | 788 | . 472 | 497. 7 | 90.3 | 4. 72 | 175. 8 | 31. 9 | 2. 81 |
| 30 | 300 | 81. 3 | 23. 87 | 11. 81 | 11. 811 | 788 | . 472 | 618.8 | 105. 0 | 5. 08 | 216. 4 | 36. 6 | 3.01 |
| 32 | 320 | 90. 7 | 26. 51 | 12. 60 | 11. 811 | 866 | 512 | 774.6 | 123. 3 | 5. 39 | 238.0 | 40. 3 | 2. 99 |
| 34 | 340 | 92. 1 | 26. 97 | 13. 39 | 11. 811 | 866 | 512 | 887. 3 | 132.4 | 5. 71 | 238.0 | 40. 3 | 2. 97 |
| 36 | 360 | 100.8 | 29. 76 | 14. 17 | 11. 811 | 94.5 | 551 | 1, 083.8 | 153. 2 | 6. 02 | 259. 7 | 44. 0 | 2. 96 |
| 38. | 380 | 102. 8 | 30.07 | 14. 96 | 11. 811 | 945 | 551 | 1, 223. 8 | 163.5 | 6. 38 | 259. 7 | 44. 0 | 2. 94 |


|  | 40 | 400 | 110. 2 | 32. 40 | 15. 75 | 11. 811 | 1. 024 | . 551 | 1, 456. 6 | 184.9 | 6. 69 | 281. 3 | 47.7 | 2. 95 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 421/2 | 425 | 111.5 | 32.86 | 16.73 | 11.811 | 1. 024 | . 551 | 1, 668.9 | 199.5 | 7. 13 | 281.3 | 47.7 | 2. 93 |
|  | 45 | 450 | 122. 3 | 35. 96 | 17. 71 | 11.811 | 1. 102 | . 591 | 2, 023.0 | 228. 2 | 7. 48 | 303. 1 | 51.3 | 2. 91 |
| \% | 471/2 | 475 | 124. 3 | 36. 43 | 18. 70 | 11.811 | 1. 102 | 591 | 2, 284. 8 | 244. 7 | 7. 91 | 303. 1 | 51.3 | 2. 88 |
| $\stackrel{8}{8}$ | 50 | 500 | 134. 4 | 39.53 | 19. 59 | 11.811 | 1. 181 | . 630 | 2, 719.1 | 276.4 | 8. 27 | 325. 0 | 55.0 | 2. 87 |
|  | 55 | 550 | 139. 1 | 40.77 | 21. 65 | 11.811 | 1. 181 | . 630 | 3, 370.0 | 311.2 | 9. 09 | 325.0 | 55.0 | 2. 82 |
| 8 | 60 | 600 | 152. 5 | 44. 80 | 23. 62 | 11.811 | 1. 260 | . 669 | 4, 342. 8 | 368.0 | 9. 84 | 346.8 | 58.7 | 2. 78 |
|  | 65 | 650 | 157. 2 | 46.04 | 25. 59 | 11.811 | 1. 260 | . 669 | 5, 207.5 | 407.0 | 10.62 | 346. 8 | 58. 7 | 2. 74 |
|  | 70 | 700 | 170.6 | 50.22 | 27. 56 | 11.811 | 1. 339 | . 709 | 6, 492.6 | 471. 1 | 11.37 | 368. 7 | 62. 2 | 2. 71 |
| \% | 75 | 750 | 175. 4 | 51.62 | 29. 53 | 11.811 | 1. 339 | . 709 | 7, 597. 5 | 514. 4 | 12. 12 | 368. 7 | 62. 2 | 2. 67 |
|  | 80 | 800 | 180. 0 | 53.01 | 31. 50 | 11.811 | 1. 339 | . 709 | 8, 800.9 | 558.9 | 12. 87 | 368. 7 | 62.2 | 2. 64 |
|  | 85 | 850 | 196. 2 | 57.66 | 33. 46 | 11.811 | 1. 417 | . 748 | 10,662. 5 | 637.0 | 13. 62 | 390.8 | 65.9 | 2. 60 |
|  | 90 | 900 | 200. 9 | 59.05 | 35. 43 | 11.811 | 1. 417 | . 748 | 12, 154. 1 | 686.5 | 14. 33 | 390.8 | 65.9 | 2. 58 |
|  | 95 | 950 | 206.3 | 60.61 | 37. 40 | 11.811 | 1. 417 | . 748 | 13, 763.5 | 735.9 | 15. 07 | 390.8 | 65.9 | 2. 54 |
|  | 100 | 1, 000 | 211.0 | 62. 00 | 39. 37 | 11.811 | 1. 417 | . 748 | 15, 485. 7 | 787. 2 | 15. 78 | 391.0 | 65.9 | 2. 51 |

159. Dimensions and Properties of Russian I-Beams

Table 164. Russian I-Beams


| Number of profile | Depth in miliimeters | Weight per foot | Area | Depth In inches | Flange |  | $\begin{aligned} & \text { Web } \\ & \text { thickness } \end{aligned}$ | Axis $\mathrm{X}-\mathrm{X}$ |  |  | Axis $\mathrm{Y}-\mathrm{Y}$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Width | Thickness |  | I | 8 | r | I | S | r |
| - | Millimeters | Pounds | Inches | Inches | Inches | Inches | Inches | Inches | Inches | . Inches | Inches | Inches | Inches |
| 10 | 100 | 7. 5 | 2.21 | 3.94 | 2. 677 | 0. 299 | 0. 177 | 5. 9 | 3.0 | 1. 63 | 0.79 | 0.59 | $0.60$ |
| 12 | 120 | 9. 4 | 2. 76 | 4. 72 | 2. 913 | . 331 | . 197 | 10. 5 | 4. 4 | 1. 95 | 1. 13 | . 77 | . 63 |
| 14 | 140 | 11. 4 | 3. 33 | 5.51 | 3. 149 | . 358 | . 217 | 17. 1 | 6.2 | -2. 26 | 1. 55 | . 98 | . 68 |
| 16 | 160 | .13. 8 | 4.05 | 6. 30 | 3. 465 | -. 390 | . 236 | 27. 1 | 8. 6 | 2. 59 | 2. 24 | 1. 29 | . 74 |
| 18. | 180 | 16. 2 | 4. 74 | 7. 09 | 3. 701 | . 421 | . 256 | 39. 9 | 11. 3 | 2. 90 | 2. 93 | 1. 59 | . 79 |
| 20a | 200 | 18. 7 | 5. 50 | 7. 87 | 3. 937 | . 449 | . 276 | 56. 9 | 14. 5 | 3. 21 | 3. 79 | 1.92 | . 84 |
| 20 b | 200 | 20.9 | 6. 12 | 7. 87 | 4. 016 | . 449 | . 354 | 60.1 | 15. 3 | 3. 14 | 4. 06 | 2. 02 | . 81 |
| 22a | 220 | 22.2 | 6.51 | 8. 66 | 4.331 | . 484 | . 295 | 81.7 | 18. 9 | 3. 54 | 5. 40 | 2. 50 | . 91 |
| 22 b | 220 | 24. 5 | 7. 19 | 8. 66 | 4. 409 | . 484 | . 374 | 85.8 | 19.8 | 3. 46 | 5. 74 | 2. 61 | . 89 |
| 24 a | 240 | 25.1 | 7. 39 | 9.45 | 4. 567 | . 512 | . 315 | 109. 8 | 23.3 | 3. 85 | 6. 73 | 2.95 | . 95 |
| 24b | 240 | 27.7 | 8. 15 | 9. 45 | 4. 645 | . 512 | . 394 | 115. 3 | 24.4 | 3. 77 | 7. 13 | 3. 08 | . 94 |
| 27a | 270 | 28. 8 | 8. 46 | 10. 63 | 4. 803 | . 539 | . 335 | 157. 3 | 29.6 | 4. 29 | 8. 29 | 3. 45 | . 99 |
| 27 b | 270 | 31.7 | 9. 30 | 10.63 | 4. $8 \dot{81}$ | . 539 | . 413 | 165. 0 | 31. 1 | 4. 21 | 8. 79 | 3. 59 | . 97 |
| 30a | 300 | 32. 3 | 9. 49 | 11.81 | 4. 961 | . 567 | . 354 | 215.0 | 36. 4 | 4. 76 | 9.61 | 3. 87 | 1. 00 |
| 30 b | 300 | 35. 4 | 10. 41 | 11.81 | 5. 039 | . 567 | . 433 | 225.8 | 38.3 | 4.65 | 10. 14 | 4. 02 | . 98 |
| 30s | 300 | 38. 6 | 11.38 | 11.81 | 5. 118 | . 567 | . 512 | 236.6 | 40. 1 | 4.57 | 10. 69 | 4. 18 | . 97 |


| 33a | 330 | 35.9 | 10. 56 | 12. 99 | 5. 118 | 591 | . 374 | 285. 8 | 44. 0 | 5. 20 | 11. 05 | 4. 31 | 1. 06 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 33b | 330 | 39.4 | 11. 58 | 12. 99 | 5. 196 | . 591 | . 453 | 300.3 | 46. 2 | 5. 08 | 11. 63 | 4. 47 | 1. 00 |
| 33 s | 330 | 42. 9 | 12. 60 | 12.99 | 5. 275 | . 591 | . 531 | 314. 7 | 48. 4 | 5. 00 | 12. 25 | 4. 64 | . 99 |
| 36 a | 360 | 40.3 | 11. 83 | 14. 17 | 5. 354 | . 622 | . 394 | 378. 6 | 53.4 | 5. 67 | 13. 26 | 4. 95 | 1. 06 |
| 36 b | 360 | 44. 1 | 12.94 | 14. 17 | 5. 433 | . 622 | . 472 | 397. 1 | 56. 1 | 5. 55 | 13. 98 | 5. 14 | 1. 04 |
| 36 s | 360 | 47.8 | 14. 06 | 14. 17 | 5. 511 | 622 | . 551 | 415. 8 | 58. 7 | 5. 43 | 14. 70 | 5. 33 | 1. 02 |
| 40a | 400 | 45.4 | 13. 35 | 15. 75 | 5. 590 | 650 | . 413 | 521. 7 | 66.5 | 6. 26 | 15. 85 | 5. 69 | 1. 09 |
| 40b | 400 | 49.6 | 14. 59 | 15.75 | 5. 669 | . 650 | . 492 | 547. 2 | 69.6 | 6. 14 | 16. 62 | 5. 87 | 1. 07 |
| 40 s | 400 | 53.8 | 15. 81 | 15. 75 | 5. 748 | . 650 | 571 | 572.9 | 72.6 | 5. 98 | 17. 46 | 6. 08 | 1. 04 |
| 45 a | 450 | 54. 0 | 15. 81 | 17. 71 | 5. 906 | 709 | 453 | 774.4 | 87. 3 | 6. 97 | 20. 53 | 6. 96 | 1. 14 |
| 45b | 450 | 58.7 | 17. 21 | 17.71 | 5. 984 | 709 | 531 | 810.9 | 91. 5 | 6. 85 | 21. 47 | 7. 20 | 1. 12 |
| 45 s | 450 | 63.5 | 18. 60 | 17. 71 | 6. 062 | . 709 | . 610 | 847.4 | 95.8 | 6. 73 | 22. 53 | 7. 44 | 1. 10 |
| 50 a | 500 | 62.9 | 18. 45 | 19.69 | 6. 220 | . 787 | . 472 | 1, 116. 2 | 113. 5 | 7. 76 | 26. 90 | 8. 66 | 1. 21 |
| 50 b | 500 | 67.9 | 20. 00 | 19. 69 | 6. 299 | . 787 | . 551 | 1, 166. 4 | 118. 4 | 7. 64 | 28. 10 | 8.91 | 1. 19 |
| 50s | 500 | 73.2 | 21. 55 | 19. 69 | 6. 378 | . 787 | . 630 | 1, 216.4 | 126.9 | 7. 48 | 29. 30 | 9. 21 | 1. 17 |
| 55 a | 550 | 70. 6 | 20. 77 | 21. 65 | 6. 535 | 827 | . 492 | 1, 510. 1 | 139. 7 | 8. 50 | 32. 91 | 10. 01 | 1. 26 |
| 55b | 550 | 76. 6 | 22. 48 | 21. 65 | 6. 614 | . 827 | . 571 | 1, 576. 7 | 145. 8 | 8. 35 | 34. 11 | 10. 37 | 1. 24 |
| 55 s | 550 | 82. 7 | 24. 18 | 21. 65 | 6. 692 | . 827 | . 650 | 1, 643. 2 | 151. 9 | 8. 23 | 35. 55 | 10. 68 | 1. 21 |
| 60a | 600 | 79. 3 | 23. 41 | 23. 62 | 6. 929 | . 866 | . 512 | 2, 014. 3 | 170.9 | 9. 25 | 40. 83 | 11. 78 | 1. 32 |
| 60 b | 600 | 86. 0 | 25. 27 | 23. 62 | 7. 008 | 866 | 591 | 2, 100. 8 | 178. 2 | 9. 13 | 42.52 | 12. 14 | 1. 30 |
| 60s | 600 | 92. 1 | 27. 13 | 23. 62 | 7. 086 | 866 | . 669 | 2, 187. 3 | 185. 5 | 8. 98 | 44. 20 | 12. 51 | 1. 28 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

160. Dimensions and Properties of Spanish Beams

Table 165. Spanish Beams


| Number of profile |
| :--- |


| 皆 | 22 | 220. | 21.4 | 6. 14 | 8. 66 | 3. 858 | . 481 | . 319 | 73. 5 | 17.0 | 3. 46 | 3.9 | 2. 0 | 80 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 24 | 240 | 24.3 | 7. 14 | 9.45 | 4. 173 | . 516 | . $3 \pm 3$ | 101. 9 | 21.6 | 3. 78 | 5. 3 | 2. 5 | . 86 |
|  | 25 | 250 | 26.1 | 7. 67 | 9. 55 | 4. 331 | . 535 | . 354 | 112. 4 | 22.8 | 3. 93 | 6.1 | 2. 8 | . 89 |
|  | 26 | 260 | 28.2 | 8. 29 | 10. 24 | 4. 449 | . 556 | . 370 | 138.0 | 27. 0 | 4. 09 | 6. 9 | 3. 1 | . 91 |
|  | 28 | 280 | 32. 2 | 9. 47 | 11.02 | 4. 685 | . 599 | . 398 | 182.2 | 33.1 | 4. 37 | 7. 2 | 3. 7 | . 96 |
|  | 30 | 300 | 36.4 | 10. 71 | 11. 81 | 4. 921 | . 638 | . 425 | 235.4 | 39.8 | 4. 69 | 10.8 | 4. 4 | 1. 00 |
|  | 32 | 320 | 41. 0 | 12. 06 | 12.60 | 5. 157 | . 681 | . 453 | 300. 5 | 47.7 | 5. 00 | 13.3 | 5. 2 | 1. 05 |
|  |  | 340 | 45.7 | 13. 45 | 13. 39 | 5. 394 | . 721 | . 480 | 383.5 | 56. 3 | 5. 31 | 16. 2 | 6. 0 | 1. 10 |
|  |  | 360 | 51. 2 | 15. 05 | 14. 17 | 5. 630 | . 767 | . 519 | 470.9 | 66.5 | 5. 59 | 19.6 | 7. 0 | 1. 14 |
|  |  | 380 | 56.4 | 16. 59 | 14.96 | 5. 866 | . 807 | . 539 | 576.8 | 76.9 | 5. 91 | 23. 4 | S. 0 | 1. 19 |
|  |  | 400 | 62. 2 | 18. 29 | 15. 75 | 6. 102 | . 851 | . 567 | 701.7 | S9. 1 | 6. 18 | 27.9 | 9. 1 | 1. 23 |
|  |  | 450 | 77.5 | 22. 79 | 17. $\overline{7} 2$ | 6. 693 | . 958 | . 638 | 1, 101. 4 | 124. 5 | 6.97 | 41.6 | 12.4 | 1. 35 |
|  |  | 500 | 94.9 | 27. 90 | 19.69 | 7. 283 | 1. 063 | . 709 | 1, 651. 1 | 167.8 | 7.72 | 59.6 | 16. 4 | 1. 46 |
|  |  | 550 | 112.5 | 33. 02 | 21. 65 | 7. 874 | 1. 181 | . 748 | 2, 382. 4 | 220.3 | S. 50 | S3. 8 | 21.3 | 1. 58 |

## 161. Safe Loads on Angles and Steel Pipes

a. Safe Loads on Angles Used as Beams. Allowable uniform load in kips for angles supported laterally and with longer leg vertical are shown in table 166.

Table 166. Safe Loads on Angles in Kips

b. Safe Loads on Steel-Pipe Columns. Allowable concentric loads in kips are given in table 167. The loads below the heavy lines are for secondary members with $l / r$ ratios between 120 and 200. For main members of these lengths, use the column formula in paragraph $149 a$ and radii of gyration in paragraph 151.

Table 167. Safe Loads on Pipes
Standard

| Unbraced length (feet) | Nominal diameter-weight per foot |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 12 |  | 10 |  |  | 8 |  | 6 | 5 | 4 | 31/2 | 3 |
|  | 49.56 | 43.77 | 40.48 | 34.24 | 31.20 | 28.55 | 24.70 | 18.97 | 14.62 | 10.79 | 9.11 | 7.58 |
|  | 246 | 217 | 200 | 169 | 154 | 140 | 121 | 92 | 70 | 50 | 42 | 33 |
| 8. | 244 | 216 | 199 | 168 | 153 | 138 | 120 | 90 | 68 | 47 | 38 | 30 |
| 10 | 243 | 214 | 196 | 166 | 151 | 136 | 118 | 86 | 64 | 44 | 35 | 26 |
| 12 | 240 | 212 | 194 | 164 | 149 | 133 | 115 | 82 | 61 | 40 | 30 | 21 |
| 14 | 237 | 210 | 190 | 161 | 147 | 129 | 112 | 79 | 56 | 34 | 25 | 18 |
| 16 | 234 | 207 | 187 | 158 | 144 | 125 | 109 | 74 | 51 | 30 | 22 | 16 |
| 18 | 231 | 204 | 182 | 154 | 141 | 121 | 105 | 69 | 45 | 26 | 19 | 13 |
| 20 | 227 | 200 | 178 | 151 | 137 | 115 | 100 | 63 | 41 | 23 | 17 |  |
| 22 | 222 | 196 | 172 | 146 | 133 | 109 | 95 | 56 | 37 | 21 | 15 |  |

Table 167. Safe Loads on Pipes-Continued

| IExtra strong |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Unbraeed length (feet) | Nominal diameter-weight per foot |  |  |  |  |  |  |  |
|  | 12 | 10 | 8 | 6 | 5 | 4 | $31 / 2$ | 3 |
|  | 65.42 | 54.74 | 43.39 | 28.57 | 20.78 | 14.98 | 12.51 | 10.25 |
| 6. | 325 | 271 | 213 | 139 | 99 | 70 | 58 | 45 |
| 8. | 323 | 268 | 210 | 135 | 96 | 65 | 53 | 40 |
| 10. | 320 | 265 | 206 | 131 | 91 | 60 | 47 | 35 |
| 12 | 317 | 261 | 201 | 125 | 85 | 54 | 40 | 28 |
| 14. | 313 | 257 | 196 | 119 | 79 | 47 | 34 | 24 |
| 16. | 309 | 252 | 189 | 112 | 71 | 40 | 30 | 21 |
| 18. | 304 | 246 | 192 | 103 | 63 | 36 | 26 | 18 |
| 20-.-- | 299 | 239 | 173 | 94 | 56 | 32 | 23 | ---- |
| 22...--- | 293 | 232 | 164 | 84 | 51 | 28 |  |  |
| 24------ | 286 | 224 | 155 | 77 | 46 | 25 | --- | ----- |

Double extra strong

| Unbraced length (feet) | Nominal diameter-weight per foot |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 8 | 6 | 5 | 4 | 31/2 | 3 |
|  | 72.42 | 53.16 | 38.55 | 27.54 | 22.85 | 18.58 |
| 6.-. | 355 | 257 | 183 | 130 | 103 | 80 |
| 8 | 350 | 249 | 176 | 118 | 93 | 70 |
| 10. | 343 | 240 | 165 | 108 | 82 | 59 |
| 12 | 334 | 228 | 154 | 94 | 68 | 48 |
| 14. | 324 | 213 | 140 | 79 | 58 | 40 |
| 16 | 312 | 200 | 125 | 70 | 50 | 34 |
| 18 | 299 | 182 | 109 | 61 | 43 |  |
| 20. | 284 | 163 | 98 | 54 | 38 |  |
| 22 | 269 | 147 | 88 | 47 |  |  |
| 24. | 250 | 135 | 80 |  |  |  |
| 26... | 2:30 | 124 | 72 |  |  |  |
|  |  |  |  |  |  |  |

## 162. Riveted Connections

a. Machinc fabrication of structural steel for buildings requires a uniform diameter for rivets and ficld bolts for riveted and bolted structures. It is universal practice to use $3 / 4-$ inch rivets and bolts in ${ }^{13} / 1 / \mathbf{- i n c h}$ punched holes in such structures. A minimum steel thiekness of $5 / 16$ inch is required to develop bearing value equivalent to the shearing value of a $3 / 4$-inch rivet. For $3 / 4$-inch rivets the minimum driving clearance for satisfactory shop riveting is $1 \frac{1 / 4}{}$ inches from the center of the rivet, so that the narrowest angle leg satisfactory for $\frac{3 / 4}{}$-inch rivets is 3 inches (usual gage is $13 / 4$ inches for 3 -inch angles).

The lightest member composed of a pair of angles for a riveted truss is thus two angles 3 by $21 / 2$ by $5 / 16$ inches, and the minimum gusset-plate thickness is thus $5 / 16$ inch. The above factors affect the spacing and panel arrangements of riveted trusses. Usual gages for various angles (in inches) are-


b. The minimum WF section suitable for use as a column to receive the ends of floorbeams from two directions $90^{\circ}$ apart is an 8 - by $6 \frac{1 / 2-}{2-}$ inch WF, 24 pounds per foot. Seated connections with rivets $3 \not / 2$ inches center to center can be riveted or bolted to flanges and web of this section. The usual rivet gage is $31 / 2$ inches in WF beam flanges $61 / 2$ to $71 / 2$ inches wide, and $51 / 2$ inches in flanges 8 inches and wider. The 8 - by 8 -inch WF, 31 pounds per foot, is therefore the lightest section on which standard connection angles can be riveted or bolted to the flanges.

## 163. Welded Connections

a. Types of Welded Joints. The joints shown in figure 76 are types accepted without qualification under the A.W.S. code and under the A.I.S.C. specifications.
b. Welding Symbols for Use on Drawings. The symbols shown in figure 77 are those developed by the American Welding Society for use on drawings specifying arc or gas welding. See also TM 5-704.
c. Effective Areas of Weld Metal. The strength of welded connections is based on unit stresses for welds as given in paragraph $149 a$ and on effective areas of weld metal as shown in table 168.


Figure 76. Types of welded joints.


Figure 76-Continued

Table 168. Effective Weld Areas

| Type of weld | Effective length | Effective throat thickness |
| :---: | :---: | :---: |
| Butt welds, complete penetration. <br> Butt welds, incomplete penetration. | Width of part joined.-- | Thiekness of thinner part joined. <br> $75 \%$ of thickness of thinner part joined. |
| Fillet welds. | Over-all length of fullsize fillet, including returns. | Shortest distance from root to faee ( 0.707 times nominal size for an equal-leg $45^{\circ}$ weld.) |

Shearing area is nominal area of hole or slot in plane of faying (eontact) surfaee.
Shearing area is effective area of fillet, but not to exeeed nominal area of hole or slot.

| ARC AND GAS WELDING SYMBOLS |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| TYPE OF WELD |  |  |  |  |  |  |  | FIELD WELD | $\begin{aligned} & \text { WELD } \\ & \text { ALL } \\ & \text { AROUND } \end{aligned}$ | FLUSH |
| BEAD | Fillet | GROOVE |  |  |  |  | $\begin{array}{\|c\|} \hline \text { PLUG } \\ \hline 8 S L O T \\ \hline \end{array}$ |  |  |  |
| BEAD | FILLE | SQuARE | $V$ | BEVEL | U | J |  |  |  |  |
|  |  | $11$ |  | $V$ |  | $\bigcirc$ | L | 0 | $\bigcirc$ |  |
| LOCATION OF WELDS |  |  |  |  |  |  |  |  |  |  |
| ARROW (OR NEAR) SIDE OF JOINT |  |  |  | OTHER (OR FAR) SIDE OF JOINT |  |  | BOTH SIDES OF JOINT |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |

1. THE SIDE OF THE JOINT TO WHICH THE ARROW POINTS IS THE ARROW (OR NEAR) SIDE AND THE OPPOSITE SIDE OF THE JOINT IS THE OTHER (OR FAR) SIDE.
2. ARROW SIDE AND OTHER SIDE WELDS ARE SAME SIZE UNLESS OTHERWISE SHOWN.
9 SYMBOLS APPLY BETWEEN ABRUPT CHANGES IN DIRECTION OF JOINT OR AS DIMENSIONED, (EXCEPT WHERE ALL AROUND SYMBOL IS USED). -.
4 ALL WELDS ARE CONTINUOUS AND OF USER'S STANDARO PRO. PORTIONS, UNLESS OTHERWISE SHOWN
5 TAIL OF ARROW USED FOR SPECIFICATION REFERENCE TTAIL MAY BE OMITTED WHEN REFERENCE NOT USED.)
E. G. "C. A."-AUTOMATIC SHIELDED CARBON ARC
"S. A."-AUTOMATIC SUBMERGED ARC

6 IN JOINTS IN WHICH ONE MEMBER ONLY IS TO BE GROOVEO. ARROW POINTS TO THAT MEMBER
7. DIMENSIONS OF WELD SIZES. INCREMENT LENGTHS. AND SPAC. INGS. IN INCHES.

Figure 77. Welding symbols


Figure 78. Typical welded-beam connections.
d. Requirement for Unrestrained Beam Connections. The ends of beams and girders must be frce to rotate slightly under deflection, by a horizontal displacement of the top flange. Normally this is accomplished by welding only the ends of all connection angles except seat angles, to permit the angles to bend slightly. The amount of horizontal displacement to be provided for is-
$e=0.007 d$ for beams designcd for full uniform loads and for deflections not over $1 / 360$ span.
or, $e=\frac{f L}{3,625,000}$ for bcans designed for full uniform loads producing stress $f$ at midspan.
Where $e=$ horizontal displacement of top flange in inchcs.
$d=$ depth of beam in inches.
$f=$ unit stress in pounds per square inch.
$L=$ span of beam in feet.
e. Details for Welded Connections. Typical details recommended by the American Institute of Steel Construction arc shown in figures 78, 79, and 80.


Figure 79. Column bases and splices.


Figure 80. Crane column bases and splices.

## Section IV. REINFORCED CONCRETE

## 164. Working Stresses

a. Determination of strength of concrete at 28 days. For plastic mixes, using standard Portland cement and sound, clean, well-graded aggregates, the strength and other desirable properties of concrete under given job conditions are governed by the net quantity of mixing water used per unit of cement. Strength_is increased as the quantity of water is reduced. The lowest practicable water-cement ratio is determined by trial mixes. Table 169 gives suggested water-cement ratios for various concrete sections, climatic conditions, and types of structure. The probable 20-day strength is determined from table 170. To allow for field conditions, normally the tabulated strengths are reduced 15 percent pending actual tests.
b. Slump. See paragraph 186.
c. Allowable Unit Stresses in Concrete. The allowable unit stresses in concrete, in pounds per square inch, shall not exceed the values shown in table 171 , where $f^{\prime}{ }_{c}$ is the minimum specified compressive strength at 28 days, or at such lesser age as the concrete may be expected to receive its full load. This is based on the following assumptions:
(1) That the proportions of cement, aggregate, and water have been determined by a method approved by the American Concrete Institute.
(2) That reinforced concrete nembers have been designed with reference to allowable stresses, working loads, and the accepted straight-line theory of flexure. In determining

## Type or location of structure

A. At the waterline in hydraulie or waterfront structures or portions of sueh structures where eomplete saturation or intermittent saturation is possible, but not where the strueture is continuously subinerged in water-
B. Portions of hydraulie or waterfront struetures some distance from waterline, but subject to frequent wetting by water $\qquad$
C. Ordinary exposed struetures, buildings, and portions of .bridges not eoming under above groups
D. Complete continuous submergenee in water
E. Conerete deposited through water- $\qquad$
F. Pavement slabs directly on ground: Wearing slabs

Scvere or moderate clunate, wide range of
templucrature, rann, aut long freczing speclls
or or frecquent freczing and thawing

Mild climate, rain, or semiarld; rarely suow or frost

| (Gallous/sack 1) |  |  | (Gallons/saek 1) |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{aligned} & \text { Thin } \\ & \text { scctions } \end{aligned}$ | Moderato sections | Mass sections | Thin scctions | Moderato sectlons | Mass sectious |
| 5 | 51/2 | 6 | 5 | 51/2 | ${ }^{\cdot}$ |
| 51/2 | 6 | 6 | 51/2 | 61/2 | 7 |
| 6 | 61/2 | 7 | 6 | 7 | 71/2 |
| 6 | 61/2 | 7 | 6 | 61/2 | 7 |
| ${ }^{2}$ ) | 51/2 | 51/2 | ${ }^{2}$ ) | 51/2 | 51/2 |
| 51/2 | $\left({ }^{2}\right)$ | (2) | 6 | ( ${ }^{\text {a }}$ | ( ${ }^{\text {a }}$ |
| 61/2 | (2) | ( ${ }^{2}$ | 7 | ${ }^{(2)}$ | $\left({ }^{2}\right)$ |

G. Special case. For conerete not exposed to the weather, such as interiors of buildings and portions of structures entirely below ground, no exposure hazard is involved and the water-eement ratio should be selected on the basis of the strength and workability requirements.
${ }^{1}$ The figures in this table correspond to U.S. 94 -pound bags.
${ }^{2}$ These sections not practicable for the purposo intended.

Table 170. Compressive Strengths at 28 Days (for Type I Cement)

| Compressive strength at 28 days (pounds per square inch) | Gallons per bag ${ }^{1}$ | Ratio of water to cement |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Cuhic feet per bag ${ }^{1}$ | Volume of water to absolute volume of cement | Weight of water to weight of cement |
| 6,000 | 4 | 0. 535 | 1. $12: 1$ | 0. $355: 1$ |
| 5,000 | 5 | . 668 | 1. $40: 1$ | . 444 : 1 |
| 4,000 | 6 | . 802 | 1. $68: 1$ | . $533: 1$ |
| 3,300 | 7 | . 936 | 1. $95: 1$ | . $621: 1$ |
| 2,800 | 8 | 1. 069 | 2. $23: 1$ | . $710: 1$ |

${ }^{1}$ The figures in this table correspond to U.S. 94 -pound bags.
the ratio $n$ for design purposes, the modulus of elasticity for the concrete shall be assumed as $1,000 f^{\prime}{ }_{c}$ and that for steel as $30,000,000$ pounds per square inch; the steel shall be assumed to take all tension stresses in flexural computations.
d. Allowable Unit Stresses in Reinforcement. ${ }^{1}$ In general, steel for concrete reinforcement should not be stressed in excess of the following limits:
(1) Tension. 20,000 pounds per square inch for rail-steel concrete reinforcing-bars, -billet-steel concrete reinforcing bars of intermediate and hard grades, axle-steel concrete reinforcing bars of intermediate and hard grades, and cold-drawn steel wire for concrete reinforcement. 18,000 pounds per square inch for billet-steel and axle-steel concrete reinforcing bars of structural grade.
(2) Tension in one-way slabs of not more than 12-foot span. For the main reinforcement, $3 / 8$ inch or less in diameter, 50 percent of the minimum yield point specified in A.S.T.M. specifications for the particular kind and grade of reinforcement used, but in no case to exceed 30,000 pounds per square inch.
(3) Compression, vertical-column reinforcement. Forty percent of the minimum yield point specified in A.S.T.M. specifications for the particular kind and grade of reinforcement used, but in no case to exceed 30,000 pounds per square inch. For structural-steel sections, 16,000 pounds per square

[^36]Table 171. Allowable Unit Stresses

| Description |
| :--- |


| Deseription |  | For any strength of conerete determined by standard methorls$n=\frac{30,000}{f_{c}^{\prime}}$ | $\begin{aligned} & \text { Maximum } \\ & \text { value } \\ & \text { (pounds 1er } \\ & \text { square inch) } \end{aligned}$ | For strength of conerete shown below |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{gathered} f_{c}=2,000 \\ \text { nound } 1 \text { er } \\ \text { square inch; } \\ n=15 \end{gathered}$ |  | $\begin{gathered} f_{c}^{\prime}=2,500 \\ \text { nounds per } \\ \text { square ineh; } \\ n=12 \end{gathered}$ | $\begin{gathered} f_{c}^{\prime}=3,000 \\ \text { 1ounds ber } \\ \text { square ineh; } \\ n=10 \end{gathered}$ |  | $\begin{gathered} f_{t}^{\prime}=5,000 \\ \text { ipounds per } \\ \text { square ineh; } \\ n=6 \end{gathered}$ |
| Plain bars ${ }^{4}$ (must be hooked): Top bars ${ }^{3}$ | $u$ |  | $0.03 f_{c}^{\prime}$ | 105 | 60 | 75 | 90 | 105 | 105 |
| In 2-way footings (except top bars). | $u$ | $0.036 f_{c}^{\prime}-\ldots-$ | 126 | 72 | 90 | 108 | 126 | 126 |
| All others | $u$ | $0.045 \int_{c}^{\prime} \ldots \ldots$ | 158 | 90 | 113 | 135 | 158 | 158 |
| Bearing: $f_{c}$ |  |  |  |  |  |  |  |  |
| On full area | $f_{c}$ | $0.25 f_{c}^{\prime}$ |  | 500 | 625 | 750 | 938 | 1,250 |
| On one-third area or less ${ }^{5}$ - | $f_{c}$ | $0.375 f_{c}^{\prime}$ |  | 750 | 938 | 1, 125 | 1, 405 | 1,875 |

1 Plain hars in footing slabs must he anchored by means of standard hooks. The center faces of these hooks, and the ends of deformed hars, nust he not less than 3 inches nor more than 6 inches from the face of the footing. In isolated footings the sleearing unlt stress on the critical section shall not exceed $0.03 f_{c}^{\prime}$, nor in any case shall it exeeed 75 pounds per square inch. The eritical section for shear to he used as a measure of diagonal tension shall be assumed as a vertical section obtained by passing a series of vertical planes through the footing, each of which is paraliel to a corresponding facc of the column, pedestal, or wall, and located a distance therefrom equal to the depth $d$ for footings on soil, and one-half the depth $d$ for footings on piles.
${ }^{2}$ A deformed bar is a reinforcing bar conforming to A.S.T.M. specifteations A305. Wire mesh with welded intersections not farther apart than 6 inches in the direction of the prineipai reinforeement, and with cross wires not smaller than No. 10 A. S. \& W. gage, may be rated as a deformed bar.
${ }^{3}$ ' 1 'op bars, in reference to bond, are horizontal hars so placed that not more than 12 inches of eonerete is east in the member below the bar.
4 Reinforecment which does not conform to the definition of a deformed bar shall be classed as a plain har.
${ }^{5}$ This increase siall he permitted only when the least distance between the edges of the loaded and unloaded areas is a minimum of $1 / 4$ of the parallel side dimension of the loaded area. The allo wahle hearing stress on a reasonahle concentric area greater than $1 / 3$ but less than the full area shall be interpolated between the values given.

Data extracted from Journal of the American Conerete Institute, Muy 1056. Ikeprints by permission of Amerlcan Conerete Instltute.
inch. For cast-iron sections, $10 ; 000$ pounds per square inch. For stcel-pipc columns filled with concrete, the allowable load is determined by the formula-

$$
P=0.25 f^{\prime}{ }_{c}\left(1-0.000025 \frac{h^{2}}{K_{c}^{2}}\right) A_{c}+f^{\prime}{ }_{r} \boldsymbol{A}_{s}
$$

Wherc $P=$ allowable loads, lbs.
$f^{\prime}{ }_{c}=$ comprossive strength of concrete at 28 days unless otherwise specified, psi.
$h=$ unsupported length of column, in.
$K_{c}=$ radius of gyration of concrcte in pipc column.
$A_{c}=$ net area of concrete section, sq. in.
$A_{s}=$ cffective cross-scctional area of reinforcement in compression in column, sq. in.
$f_{r}^{\prime}$ is given by the formula-

$$
f_{r}^{\prime}=17,000-0.485 \frac{h^{2}}{K_{s}{ }^{2}}
$$

when the pipe has a yicld strength of at least 33,000 pounds per squarc inch and an $h / K_{s}$ ratio not exceeding $120 ; K_{s}$ being the radius of gyration of the stecl-pipe section.
(4) Compression, flexural members. To approximate the effect of creep, the strcss in compression reinforcement resisting bending may be taken at twice the value indicated by using the straight-line relation between stress and strain, and the modular ratio given in $164 c(2)$ above, but not of greater value than the allowable stress in tension.
e. Values for $n$. $n$, the ratio of the modulus of elasticity of steel to that of concrete, may be taken as 30,000 divided by the ultimatc compressive strength of a given concrete at 28 days.

## 165. Weights, Areas, and Spacing of Reinforcing Bars

a. Weights and arcas of plain steel bars are given in paragraph 150.
b. The designations, unit weights, and nominal dimensions of A.S.T.M. standard deformed reinforcing bars are given in table 172.
c. Table 173 shows the areas and perimetcrs of various combinations of four bars, using the nomenclature and dimensions of table 172.

Table 172. A:S.T.M. Standard Deformed Reinforcing Bars

| Bar designation number ${ }^{1}$ | Unit weight $\underset{\text { foot) }}{(\text { pounds per }}$ | Nominal dimensions |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Diameter (inches) | Cross-sectional aren (square -inches) | Perimeter (inehes) |
| $2^{2}$ | 0. 167 | 0. 250 | 0. 05 | 0. 786 |
| 3. | . 376 | . 375 | . 11 | 1. 178 |
| 4 | . 668 | . 500 | . 20 | 1. 571 |
| 5. | 1. 043 | . 625 | . 31 | 1. 963 |
| 6 | 1. 502 | . 750 | . 44 | 2. 356 |
|  | 2. 044 | . 875 | . 60 | 2. 749 |
| 8. | 2. 670 | 1. 000 | . 79 | 3. 142 |
| $9^{3}$ | 3. 400 | 1. 128 | 1. 00 | 3. 544 |
| $10^{3}$ | 4. 303 | 1. 270 | 1. 27 | 3. 990 |
|  | 5. 313 | 1. 410 | 1. 56 | 4. 430 |

${ }^{1}$ Bar numbers are based on the number of eighths of an ineh included in the nominal dlameter of the bars. The nominal diameter of a ceformed bar ls equivalent to the diameter of a plain bar having the same weight per foot as the deformed bar.
$31 / 4$-ineh bar in plain round only.
3 Bars of designations numbers 9,10 , and 11 correspond to the former 1 -ineh-square, 116 -inch-square, and $11 / 4$-ineh-square sizes and are equivalent to those former standard bar sizes in weight and nominal crosssectional areas.
The above table including the footnotes is reprinted from "Tentative Specifications for Billet-Steel Bars for Conerete Reinforcement, A.S.T.M. Designation A15-58T," revision of February 1959 by permission of the American Soclety for Testing Materlals, and is in agreement with U.S. Department of Commerce Simplified Practice Recommendation 26-50 covering Steel Reinforcing Bars.
$\therefore$ Table 173. Bar Areas and Perimeters


T'able 179. Bar Areas and Perimeters-Continued

d. Minimum Spacings and Clearances for Beam Reinforcing Bars. These are shown in figure 81. The horizontal distanees AB and CD between reinforcing bars are either 1 inch, $1 \frac{1 / 3}{}$ times maximum aggregatc size, or 1-bar diameter, whichcver is largest.
e. Concrete Protection for Reinforcement. The following are the provisions of the ACI Building Code on this subject: ${ }^{1}$
(1) The reinforeement of footings and other prineipal struetural members in whieh the eoncrete is deposited against the ground shall have not less than 3 inehes of conerete between it and the ground contact surface. If eoncrcte surfaees after removal of the forms are to be exposed to the weather

[^37]

Figure 81. Minimum spacings and clearances for beam reinforcing bars.
or be in contaet with the ground, the reinforeement shall be proteeted by not less than 2 inches of conerete for bars larger than \#5 and $1 \frac{1}{2}$ inehes for \#5 bars or snialler.
(2) The eonerete proteetive eovering for reinforeement at surfaees not exposed direetly to the ground or weather shall be not less than $\frac{3 / 4}{}$ ineh for slabs and walls; and not less than $11 / 2$ inehes for beams, girders, and eolumns. In collerete joist floors in whieh the elear distanee between joists is not more than 30 inehes, the protection of reinforeement shall be at least $3 / 4$ ineh.
(3) If the general eode of whieh this eode forms a part speeifies, as fire protective covering of the reinforeement, thieknesses of eonerete greater than those given (herein), then sueh greater thieknesses shall be used.
(4) Conerete protection for reinforeement shall in all cases be at least equal to the diameter of bars.
(5) Exposed reinforcing bars intended for bonding with future extensions shall be proteeted from eorrosion by eonerete or other adequate eovering.
(6) (For preeast concrete): At surfaees not exposed to weather, all reinforeement shall be proteeted by conerete equal to the nominal diameter of bars but not less than $5 / 8$ ineh.

## 166. Standard Notation for Beam Formulas

$A_{s}=$ area of rcinforcing bars in square inches
$b=$ width of rectangular beam, or of slab or T-beam, in inches
$b^{\prime}=$ width of stem of T-bcam, in inches
$d=$ depth of beam to center of tension reinforcing, in inches
$f_{c}=$ compressive unit stress in concrete in pounds per square inch
$f^{\prime}{ }_{c}=$ ultimate compressive strength of 28-day concrete, in pounds per squarc inch
$f_{s}=$ 'Tensile stress in reinforcing in pounds per squarc inch
$j=$ ratio of distance (jd) between resultant of compressive and tensile stresscs to cftcctive depth
$j d=$ arm of resisting couple $; j=1-\frac{k}{3}$ for rectangular bars
$k=$ ratio of distancc ( $k d$ or kt ) between cxtreme fibcr and neutral axis to effective depth or to total depth
$k d=$ depth of beam to neutral axis in inches
$K=$ coefficient of resistance bcam $\frac{M}{b d^{2}}$
$M=$ moment of resistance, or bending moment, $=\frac{1}{8} \mathrm{WL}$ for simple, uniformly loaded bcams
$n=E s / E c:$ taken as $\frac{30,000}{\text { ultimate 28-day compressive strengtli of concrete }}$
$p=$ percentage of reinforcing $=\frac{A_{s}}{b d}$
$t=$ overall dimension of column in inches; also depth of flange
$v=$ shearing strcss in pounds per square inch $=\frac{V}{b j d}$ for rectangular beams; $\frac{V}{b^{\prime} j d}$ for T-beams
$V=$ Total shear in pounds
$z=$ ratio of distance (zkd) between extreme fiber and resultant of compressive stresscs to distance kd

## 167. Design Data for Slabs and Rectangular Beams

The following data apply to rectangular beams with tension reinforcing, and to slabs reinforced in one direction when designed as rcctangular beams 1 foot wide:
a．Coefficients $K, k, j, p$ for rectanyular beams：
Table 174．Coefficionls（ $K, k, j, p$ ）for Rectangular Sections


*"Balanced steel ratio" applies to problems involving bending only.

Table 1\％̌4．Coefficients（ $K, k, j, p$ ）for Recclangular Sections－Continucd

| $\int^{\prime} \mathrm{c}$ and $n$ | $f e$ | に | $k$ | $j$ | $p$ | K | $k$ | j | $p$ | $\kappa$ | $k$ | j | $p$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $f_{0}=12,000 \quad a=0.83$ |  |  |  | $f_{0}=14,000 \quad u=0.98$ |  |  |  | $f_{a}=1 \mathrm{i}, 000 \quad a=1.13$ |  |  |  |
| 37508 | 1300 | 255 | ． 464 | ． 845 | ． 0251 | 238 | ． 426 | ． 858 | ． 0198 | 223 | ． 394 | ． 869 | ． 0160 |
|  | 1400 | 284 | ． 483 | ． 839 | ． 0282 | 265 | ． 444 | ． 852 | ． 0222 | 249 | ． 412 | ． 863 | ． 0180 |
|  | 1500 | 312 | ． 500 | ． 833 | ． 0313 | 293 | ． 461 | ． 846 | ． 0247 | 276 | ． 429 | ． 857 | ． 0201 |
|  | 1700 | 371 | ． 531 | ． 823 | ． 0376 | 350 | ． 493 | ． 836 | ． 0299 | 331 | ． 460 | ． 847 | ． 0244 |
|  | 1875 | 425 | ． 556 | ． 815 | ． 0434 | 401 | ． 517 | ． 828 | ． 0346 | 381 | ． 484 | ． 839 | ． 0284 |
|  | 2250 | 540 | ． 600 | ． 800 | ． 0563 | 514 | ． 562 | ． 813 | ． 0452 | 490 | ． 529 | ． 824 | ． 0372 |
| 5000 | 1500 | 276 | ． 429 | ． 857 | ． 0268 | 255 | ． 391 | ． 870 | ． 0209 | 238 | 360 | ． 880 | ． 0169 |
|  | 1750 | 345 | ． 467 | ． 844 | ． 0341 | 322 | ． 429 | ． 857 | ． 0268 | 301 | ． 396 | ． 868 | ． 0217 |
|  | 2000 | 417 | ． 500 | ． 833 | ． 0417 | 391 | ． 462 | ． 846 | ． 0330 | 368 | ． 429 | ． 857 | ． 0268 |
|  | 2250 | 490 | ． 529 | ． 824 | ． 0496 | 462 | ． 491 | ． 836 | ． 0395 | 436 | ． 458 | ． 847 | ． 0322 |
| 6 | 2500 | 566 | ． 556 | ． 815 | ． 0579 | 535 | ． 517 | ． 828 | ． 0462 | 508 | ． 484 | ． 839 | ． 0378 |
|  | 3000 | 720 | 600 | ． 800 | ． 0750 | 686 | ． 563 | ． 812 | ． 0603 | 654 | ． 529 | ． 824 | ． 0496 |
|  |  | $f_{5}=18,000 \quad \mathrm{a}=1.29$ |  |  |  | $f .=20,000 \quad a=1.44$ |  |  |  | $f_{1}=22,000 \quad a=1.60$ |  |  |  |
| 2000 | 700 | 113 | 0．368 | 0． 877 | 0． 0072 | 107 | 0． 344 | 0． 885 | 0． 0060 | 101 | 0． 323 | 0.892 | 0． 0051 |
|  | 750 | 126 | ． 385 | ． 87.2 | ． 0080 | 119 | ． 360 | ． 880 | ． 0068 | 112 | ． 338 | 887 | ． 0058 |
|  | 800 | 139 | ． 400 | ． 867 | ． 0089 | 131 | ． 375 | ． 875 | ． 0075 | 125 | ． 353 | 882 | ． 0064 |
|  | 900 | 165 | ． 429 | ． 857 | ． 0107 | 157 | ． 403 | ． 866 | ． 0091 | 149 | ． 380 | 873 | ． 0078 |
| 15 | 1000 | 193 | 455 | ． 848 | ． 0126 | 184 | ． 429 | ． 857 | ． 0107 | 175 | ． 405 | ． 865 | ． 0092 |
|  | 1200 | 250 | ． 500 | ． 833 | ． 0167 | 239 | ． 474 | ． 842 | ． 0142 | 230 | ． 450 | ． 850 | ． 0123 |


| 2500 | 875 | 141 | . 368 | . 877 | . 0089 | 133 | . 344 | 885 | 0075 | 126 | . 323 | 892 | 0064 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 950 | 161 | . 388 | . 871 | . 0102 | 152 | . 363 | . 879 | . 0086 | 144 | . 341 | . 886 | . 0074 |
|  | 1000 | 173 | . 400 | . 867 | . 0111 | 164 | . 375 | . 875 | . 0094 | 156 | . 353 | . 882 | 0080 |
|  | 1125 | 207 | . 429 | . 857 | . 0134 | 196 | . 403 | . 866 | . 0113 | 187 | . 380 | . 873 | . 0097 |
| 12 | 1250 | 241 | . 455 | . 848 | . 0158 | 230 | . 429 | . 857 | . 0134 | 219 | . 405 | . 865 | . 0115 |
|  | 1500 | 312 | . 500 | . 833 | . 0208 | 299 | . 474 | . 842 | . 0178 | 287 | . 450 | . 850 | . 0153 |
| 3000 | 1050 | 169 | . 368 | . 877 | . 0107 | 160 | . 344 | . 885 | . 0090 | 151 | 323 | . 892 | . 0077 |
|  | 1125 | 189 | . 385 | . 872 | . 0120 | 178 | . 360 | . 880 | . 0101 | 169 | . 338 | . 887 | . 0086 |
| 10 | 1200 | 208 | . 400 | . 867 | . 0133 | 197 | . 375 | . 875 | . 0113 | 187 | . 353 | . 882 | . 0096 |
|  | 1350 | 248 | . 429 | . 857 | . 0161 | 236 | . 403 | . 866 | . 0136 | 224 | . 380 | . 873 | . 0117 |
|  | 1500 | 289 | . 455 | . 848 | . 0190 | 276 | . 429 | . 857 | . 0161 | 263 | . 405 | . 865 | . 0138 |
|  | 1800 | 37.5 | . 500 | . 833 | . 0250 | 359 | . 474 | . 8442 | . 0213 | 344 | . 450 | . 850 | . 0184 |
| 3750 | 1300 | 209 | . 366 | . 878 | . 0132 | 197 | . 342 | . 886 | . 0111 | 186 | . 321 | . 893 | . 0095 |
|  | 1400 | 234 | . 384 | . 872 | . 0149 | 221 | . 359 | . 880 | . 0126 | 209 | . 337 | . 888 | . 0107 |
|  | 1500 | 260 | . 400 | . 867 | . 0167 | 246 | . 375 | . 875 | . 0141 | 234 | . 353 | . 882 | . 0120 |
| 8 | 1700 | 313 | . 430 | . 857 | . 0203 | 298 | . 405 | . 865 | . 0172 | 283 | . 382 | . 873 | . 0148 |
|  | 1875 | 362 | . 455 | . 848 | . 0237 | 345 | . 429 | . 857 | . 0201 | 328 | . 405 | . 865 | . 0173 |
|  | 2250 | 469 | . 500 | . 833 | . 0313 | 449 | . 474 | . 842 | . 0267 | 430 | . 450 | . 850 | . 0230 |
| 5000 | 1500 | 222 | . 333 | . 889 | . 0139 | 209 | . 310 | . 897 | . 0116 | 196 | 290 | . 903 | . 0099 |
|  | 1750 | 282 | . 368 | . 877 | . 0179 | 266 | . 344 | . 889 | . 0150 | 252 | . 323 | . 892 | . 0128 |
|  | 2000 | 347 | . 400 | . 867 | . 0222 | 328 | . 375 | . 875 | . 0188 | 311 | . 353 | . 882 | . 0160 |
| 6 | 2250 | 414 | . 429 | . 857 | . 0268 | 393 | . 403 | . 866 | . 0227 | 373 | . 380 | . 873 | . 0194 |
|  | 2500 | 482 | . 455 | . 848 | . 0316 | 460 | . 429 | . 857 | . 0268 | 438 | . 405 | . 865 | . 0230 |
|  | 3000 | 625 | . 500 | . 833 | . 0417 | 599 | . 474 | . 842 | . 0356 | 574 | . 450 | . 850 | . 0307 |

Table 174. Coefficients ( $K, k, j, p$ ) for Rectangular Sectıons-Continued

| $f^{\prime} \mathrm{c}$ and $n$ | fc | K | $k$ | -j | $p$ | k | $k$ | ${ }^{j}$ | $p$ | k | $k$ | ${ }^{j}$ | $p$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $f 8=24,0 \times 0) \quad a=1$ |  |  |  | $f s=27,000) \quad a=2.00)$ |  |  |  | $f 8=30,4000 \quad a=2.24$ |  |  |  |
| 2000 | 700 | 96 | . 304 | . 899 | . 0044 | 8! | . 280 | . 907 | . 0036 | 83 | 259 | . 914 | . 00030 |
|  | 750 | 107 | . 319 | . 894 | . 0050 | 99 | . 294 | . 902 | . 0041 | 93 | 273 | . 909 | . 0034 |
|  | 800 | 118 | . 333 | . 889 | . 0055 | 111 | . 308 | . 897 | . 0046 | 104 | 280 | . 905 | . 0038 |
|  | 900 | 143 | . 360 | . 880 | . 0067 | 133 | . 333 | . 889 | . 0055. | 125 | . 310 | . 897 | . 0047 |
| 15 | 1000 | 168 | . 385 | . 872 | . 0080 | 157 | . 357 | . 881 | . 0066 | 148 | . 333 | . 889 | . 0055 |
|  | 1200 | 220 | . 429 | . 857 | . 0107 | 208 | . 400 | . 867 | . 0089 | 197 | . 375 | . 875 | . 0075 |
| 2500 | 875 | 120 | . 304 | 899 | . 0055 | 111 | . 280 | . 907 | . 0045 | 104 | 259 | . 914 | 0038 |
|  | 950 | 137 | . 322 | . 893 | . 0064 | 127 | . 297 | . 90」 | . 0052 | 119 | 275 | . 908 | . 0044 |
| 12 | 1000 | 148 | . 333 | . 889 | . 0069 | 138 | . 308 | . 897 | . 0057 | 129 | 286 | . 905 | . 0048 |
|  | 1125 | 178 | . 360 | 880 | . 0084 | 167 | . 333 | . 889 | . 0069 | 156 | . 310 | . 897 | . 0058 |
|  | 1250 | 210 | . 385 | 872 | . 0100 | 197 | 357 | . 881 | . 0083 | 185 | . 333 | . 889 | . 0069 |
|  | 1500 | 276 | . 429 | . 857 | . 0134 | 260 | . 400 | . 867 | . 0111 | 246 | . 375 | . 875 | .. 0094 |
| 3000 | 1050 | 143 | . 304 | . 899 | . 0067 | 133 | . 280 | 907 | . 0054 | 124 | . 259 | . 914 | . 0045 |
|  | 1125 | 160 | . 319 | . 894 | . 0075 | 149 | . 294 | . 902 | . 0061 | 140 | . 273 | . 909 | .. 0051 |
| 10 | 1200 | 178 | . 333 | . 889 | . 0083 | 166 | . 308 | . 897 | . 0068 | 155 | . 286 | . 905 | . 0057 |
|  | 1350 | 214 | . 360 | 880 | . 0101 | 200 | . 333 | . 889 | . 0083 | 188 | . 310 | . 897 | 0070 |
|  | 1500 | 252 | . 385 | . 872 | . 0120 | 236 | . 357 | . 881 | . 0099 | 222 | . 333 | . 889 | 0083 |
|  | 1800 | 331 | . 429 | . 857 | . 00161 | 312 | . 400 | . 867 | . 0133 | 295 | . 375 | . 875 | 0113 |
| 3750 | 1300 | 176 | . 302 | . 899 | . 0082 | 164 | . 278 | . 907 | . 0067 | 153 | 257 | . 914 | 0056 |
|  | 1400 | 199 | . 318 | . 894 | . 0093 | 185 | . 293 | . 902 | . 0076 | 173 | . 272 | . 909 | . 0063 |
| 8 | 1500 | 222 | . 333 | . 889 | . 0104 | 207 | . 308 | 897 | . 0086 | 194 | . 280 | . 905 | . 0071 |
|  | 1700 | 270 | . 362 | . 879 | . 0128 | 253 | . 335 | . 888 | . 0106 | 238 | . 312 | . 896 | . 00088 |
|  | 1875 | 315 | . 385 | . 872 | . 0150 | 295 | . 357 | . 881 | . 0124 | 278 | . 333 | . 889 | . 0104 |
|  | 2250 | 414 | . 429 | . 857 | . 0201 | 390 | . 400 | . 867 | . 0166 | 369 | . 375 | . 875 | . 0141 |


| 5000 | 1500 | 186 | . 273 | . 909 | . 0085 | 172 | . 250 | . 917 | . 0069 | 160 | 231 | 923 | . 0058 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1750 | 239 | . 304 | . 899 | . 0111 | 222 | . 280 | . 907 | . 0091 | 207 | . 259 | . 914 | . 0076 |
|  | 2000 | 296 | . 333 | . 889 | . 0139 | 276 | . 308 | . 897 | . 0114 | 259 | 286 | 905 | 0095 |
|  | 2250 | 356 | . 360 | . 880 | . 0169 | 333 | . 333 | . 889 | . 0139 | 313 | . 310 | . 897 | . 0116 |
| 6 | 2500 | 420 | . 385 | . 872 | . 0201 | 393 | . 357 | . 881 | . 0165 | 370 | . 333 | . 889 | . 0139 |
|  | 3000 | 551 | . 429 | 857 | . 0268 | 520 | . 400 | . 867 | . 0222 | 492 | . 375 | . 875 | 0188 |

b. Formulas. For beams beyond the scope of table 174, the following formulas are used:
(1) $k=\frac{n f_{c}}{n f_{c}+f_{s}}$ or $\frac{p f_{s}}{1 / 2 f_{c}}$
(2) $p=\frac{f_{c} k}{2 f_{s}}$ or $\frac{A_{s}}{b d}$
(3) $j=1-\frac{k}{3} ; j d=d-\frac{k d}{3}$
(4) $K=f_{s} p j$ or $\frac{M}{b d^{2}} ; d=\sqrt{\frac{M}{b \bar{k}}}$
(5) $A_{s}=\frac{M}{f_{s} j d}$

## 168. Design Data for T-Beams

The following data apply to T-beams with adequate web reinforcement, normally provided by bending about one-half of the longitudinal bars and providing stirrups if required.
a. Determination of Width b. For T-beams or L-beams, the width $b$ may not exceed one-fourth the span length of the beam; and the effective width overhanging on either side of the stem may not exceed one-half the clear distance to the next beam or eight times the slab thickness.
b. Formulas. For beams beyond the scopc of table 175, the following formulas are used:
(1) $k=\frac{1}{1+\frac{f_{s}}{n f_{c}}} ; k d=\frac{2 n d A_{s}+b t^{2}}{2 n A_{s}+2 b t}$
(2) $j d=d-z ; z=\frac{3 k d-2 t}{2 k d-t} \times \frac{t}{3}$
(3) $K=\frac{M}{b d^{2}} ; A_{s}=\frac{M}{f_{s} j d}$
c. Design Constants. For $n=10$ and $n=15$, and for various values of $f_{s}, f_{c}$, and $t / d$, values of $k$ and $p$ are given in table 175. Interpolations are made for other values of $n, f_{s}$, and $f_{c}$.

## 169. Design of Beam Stirrups ${ }^{1}$

a. Aera of Steel. The fundamental equation for stirrups is-

$$
A_{0}=\frac{V^{\prime} s}{B f_{0} j d}
$$

[^38]where-

```
\(A_{0}=\) total cross-scetional area of stirup legs
    \(V=v^{\prime} b j d=\) total shear to be carried by stirrups
    \(\mathcal{B}=(\sin x \quad \cos x)\) with \(x=\) angle between stirrups and axis of bcam.
```

From this-

$$
A_{v}=\frac{v^{\prime} b s}{B f_{v}}, \text { or } \frac{1}{S}=\frac{v^{\prime} b}{B A_{v} f_{v}}
$$

For stirrups perpendicular to the axis of the beam, $B=1$, and the last cquation becomes-

$$
\frac{1}{S}=\frac{v^{\prime} b}{A_{v} f_{v}}
$$

In a rectangular beam or in the stem of a $T$-beam, the concretc alone is assigned to carry shear up to 3 percent of its 28-day ultimate compressive strength.
b. Number and Spacing. The detcrmination of the number and spacing of stirrups depends on the shape and area of that part of the shear diagram for which stirrups are required. The area of the sheardiagram determines the number of stirrups required, while the stirrup spacing depends also on the shape of the diagram. Shear diagrams may be considered of three types-rectangular, trapezoidal, and triangular. Only trapezoidal and triangular shear diagrams offer problems in stirrup spacing, because the spacing is constant for rectangular diagrams. The procedure is as follows:
(1) Select the type of stirrup (vertical or inclined); the total arca of stirrup legs $A_{v}$ ( $a$ above $)$ ); and the allowable steel stress $f_{0}$.
(2) Calculate the value $\frac{v^{\prime} b}{B A_{v} f_{v}}$ at the large and small ends of the shear diagram and at points of discontinuity. To obtain the value of $j$, use figure $82(1)$.
(3) Calculate $S$, the length of the base of the shear diagram.
(4) Determine the number and spacing of the stirrups. To do this, superpose the $\frac{v^{\prime} b}{B A_{0} f_{v}}$ curve on figure $82(2)$. Read the stirrup spacing where the curve crosses the hcavy vertical lines. The number of stirrups required equals the number of vertical lines intersected.
(5) Cheek by figure 82 (3) for embedment of stirrups.

| $f$ | $t / d$ | $n=15$ |  |  |  |  |  |  |  | $n=10$ |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $f_{c}=600$ |  | $f_{e}=700$ |  | $f_{c}=800$ |  | $f_{c}=900$ |  | $f_{c}=750$ |  | $f_{c}=900$ |  | $f_{e}=1200$ |  | $f_{c}=1350$ |  |
|  |  | K | $p$ | $K$ | $p$ | K | $p$ | $K$ | $p$ | $K$ | $p$ | $K$ | $p$ | $K$ | $p$ | $K$ | $p$ |
| 16,000 | 0.06 | 32 | 0. 0021 | 38 | 0.0024 | 43 | 0. 0028 | 49 | 0. 0032 | 40 | 0. 0025 | 48 | 0. 0032 | 65 | 0. 0042 | 73 | 0. 0047 |
|  | . 10 | 50 | . 0032 | 58 | . 0038 | 67 | . 0044 | 76 | . 0050 | 60 | . 0040 | 75 | . 0049 | 100 | . 0066 | 114 | . 0075 |
|  | . 14 | 64 | . 0042 | 76 | . 0051 | 88 | . 0059 | 100 | . 0067 | 77 | . 0051 | 96 | . 0063 | 132 | . 0088 | 150 | . 0099 |
|  | . 18 | 76 | . 0051 | 90 | . 0061 | 104 | . 0071 | 120 | . 0081 | 89 | . 0061 | 114 | . 0076 | 156 | . 0107 | 180 | . 0122 |
|  | . 22 | 84 | . 0057 | 100 | . 0070 | 118 | . 0082 | 136 | . 0094 | 98 | . 0068 | 126 | . 0085 | 177 | . 0122 | 204 | . 0140 |
|  | . 26 | 89 | . 0062 | 109 | . 0076 | 129 | . 0090 | 149 | . 0105 | 104 | . 0072 | 134 | . 0093 | 194 | . 0134 | 224 | . 0156 |
|  | . 30 | 93 | . 0066 | 115 | . 0082 | 137 | . 0098 | 159 | . 0113 | 107 | . 0074 | 140 | . 0098 | 206 | . 0145 | 238 | . 0169 |
|  | . 34 | 95 | . 0067 | 118 | . 0085 | 142 | . 0102 | 166 | . 0120 |  |  | 142 | . 0101 | 213 | . 0153 | 249 | . 0180 |
|  | . 38 |  |  | 120 | . 0087 | 146 | . 0106 | 171 | . 0125 |  |  |  |  | 219 | . 0158 | 256 | . 0187 |
| 18, 000 | . 06 | 32 | . 0018 | 38 | . 0021 | 43. | . 0025 | 49 | . 0028 | 39 | . 0022 | 48 | . 0027 | 65 | . 0037 | 73 | . 0042 |
|  | . 10 | 49 | . 0028 | 58 | . 0034 | 67 | . 0039 | 76 | . 0044 | 60. | . 0035 | 73 | . 0043 | 100 | . 0058 | 1.13 | . 0066 |
|  | . 14 | 62 | . 0037 | 74 | . 0044 | 86 | . 0051 | 99 | . 0059 | 75 | . 0045 | 93 | . 0055 | 130 | . 0077 | 148 | . 0088 |
|  | . 18 | 73 | . 0044 | 88 | . 0053 | 102 | . 0062 | 117 | . 0071 | 87 | . 0052 | 109 | . 0066 | 154 | . 0093 | 176 | . 0107 |
|  | . 22 | 80 | . 0049 | 98 | . 0060 | 115 | . 0071 | 133 | . 0082 | 95 | . 0057 | 120 | . 0074 | 173 | . 0106 | 199 | . 0123 |
|  | . 26 | 85 | . 0053 | 105 | . 0066 | 125 | . 0078 | 145 | . 0091 | 98 | . 0060 | 128 | . 0079 | 188 | . 0117 | 218 | . 0136 |
|  | . 30 | 88 | . 0055 | 110 | . 0069 | 132 | . $0083{ }^{\text {² }}$ | 154 | . 0097 | --- |  | 132 | . 0082 | 198 | . 0125 | 231 | . 0146 |
|  | . 34 |  |  | 113 | . 0071 | $13 \dot{6}$ | . 0087 | 160 | . 0103 |  |  |  |  | 205 | . 0130 | 241 | . 0154 |
|  | . 38 |  |  |  |  | 138 | .. 0089 | 164 | . 0106 |  |  |  |  | 207 | . 0133 | 246 | . 0159 |
|  | . 06 | 32 | . 0016 | 37 | . 0019 | 43 | : 0022 | 49 | . 0025 | 39 | . 0020 | 48 | . 0024 | 64 | . 0033 | 73 | . 0038 |
|  | . 10 | 48 | . 0025 | 57 | . 0030 | 66 | . 0035 | 75 | . 0039 | 58 | . 0031 | 72 | . 0038 | 99 | . 0052 | 113 | . 0059 |


|  | . 14 | 61 | . 0033 | 73 | . 0039 | 85 | $\because 0046$ | 97 | . 0052 | 73 | . 00339 | . 92. | . 0049 | 128 | . 00668 | 146 | . 0078 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 20,000 | . 18 | 71 | . 0038 | 86 | . 0047 | 101 | . 0055 | 116 | . 0063 | 84 | . 0045 | 106 | . 0057 | 151 | . 0082 | 174 | . 0095 |
| 9 | . 22 | 78 | . 0043 | 95 | . 0052 | 113 | . 0062 | 1.30 | . 0072 | 90 | . 0049 | 117 | . 0064 | 169 | . 0093 | 195 | . 0108 |
| 范 | . 26 | 82 | . 0045 | 102 | . 0057 | 121 | . 0068 | 141 | . 0079 | 93 | 0051 | 123 | . 0068 | 182 | . 0102 | 211 | . 0119 |
| 苟 | . 30 | 84 | . 0046 | 106 | . 0059 | 128 | . 0072 | 149 | . 0085 |  |  | 126 | . 0070 | 192 | . 0108 | 224 | . 0127 |
|  | . 34 |  |  | 107 | . 0060 | :130. | . 0074 | 154 | . 0088 |  |  |  |  | 196 | . 0112 | 231 | . 0133 |
| 8 | . 38 |  |  |  |  |  |  | 156 | .0090 . |  |  |  |  |  |  | 234 | . 0135 |

[^39]$$
\text { Values of } j=1-\frac{k-\frac{2 t}{3 d}}{2 k-\frac{t}{d}} \times \frac{t}{d} \text { and } y=\frac{1-\frac{2 t}{3 k d}}{2-\frac{t}{k d}}
$$
(a) Enter table with known value of $\frac{t}{d}$ and $k$; solect $j$.
(b) Enter table with known value of $\frac{l}{k-\frac{d}{d}}$; select $y$; compute $j=1-\frac{y_{d}^{d}}{d}$


Figure 82(1). Cocfficients for T -sections.


## Values of $d$

Deformed bars $d=\left(f_{0}-10,000\right) \frac{5 c}{f^{\prime} c}+7 c+2$
Plain bars $\quad d=\left(f_{v}-10,000\right) \frac{11.1 c}{f^{\prime} c}+7 c+2$

When web reinforcement is inclined, determine min.d by multiplying values in table by $\sin x$ ( $x$ angle between tensile and web reinforcement).

|  | Plain | Deformed |  |  | Plain | Deformed |  |  | Plain | Deformed |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 12 | 13 | 14 | 15 | 12 | 13 | 14 | 15 | 12 | 13 | 14 | 15 |
| $f_{c}$ | $f_{v}=12,000$ |  |  |  | $f_{v}=14,000$ |  |  |  | $f_{0}=16,000$ |  |  |  |
| 2000 | 6.5 | 6.5 | 8.0 | 9.5 | 9.3 | 8.4 | 10.5 | 12.6 | 12.1 | 10.3 | 13.0 | 15.8 |
| 2500 | 6.0 | 6.1 | 7.5 | 8.9 | 8.2 | 7.6 | 9.5 | 11.4 | 10.4 | 9.1 | 11.5 | 13.9 |
| 3000 | 5.6 | 5.9 | 7.2 | 8.5 | 7.5 | 7.1 | 8.8 | 10.5 | 9.3 | 8.4 | 10.5 | 12.6 |
| 3750 | 5.2 | 5.6 | 6.8 | 8.0 | 6.7 | 6.6 | 8.2 | 9.7 | 8.2 | 7.6 | 9.5 | 11.4 |
| $\mathrm{r}^{\prime}$ | $f_{v}=18,000$ |  |  |  | $f_{v}=20,000$ |  |  |  | $f_{v}=22,000$ |  |  |  |
| 2000 | 14.9 | 12.1 | 15.5 | 18.9 | 17.6 | 14.0 | 18.0 | 22.0 | 20.4 | 15.9 | 20.5 | 25.1 |
| 2500 | 12.6 | 10.6 | 13.5 | 16.4 | 14.9 | 12.1 | 15.5 | 18.9 | 17.1 | 13.6 | 17.5 | 21.4 |
| 3000 | 11.2 | 9.6 | 12.2 | 14.7 | 13.0 | 10.9 | 13.8 | 16.8 | 14.9 | 12.1 | 15.5 | 18.9 |
| 3750 | 9.7 | 8.6 | 10.8 | 13.0 | 11.2 | 9.6 | 12.2 | 14.7 | 12.6 | 10.6 | 13.5 | 16.4 |
| $f^{\prime \prime}$ | $f_{v}=24,000$ |  |  |  | $f_{v}=27,000$ |  |  |  | $f_{5}=30,000$ |  |  |  |
| 2000 | 23.2 | 17.8 | 23.0 | 28.3 | 27.3 | 20.6 | 26.8 | 32.9 | 31.5 | 23.4 | 30.5 | 37.6 |
| 2500 | 19.3 | 15.1 | 19.5 | 23.9 | 22.6 | 17.4 | 22.5 | 27.6 | 26.0 | 19.6 | 25.5 | 31.4 |
| 3000 | 16.7 | 13.4 | 17.2 | 21.0 | 19.5 | 15.3 | 19.7 | 24.1 | 22.3 | 17.1 | 22.2 | 27.2 |
| 3750 | 14.1 | 11.6 | 14.8 | 18.0 | 16.3 | 13.1 | 16.8 | 20.5 | 18.6 | 14.6 | 18.8 | 23.0 |

Figure 82(3). Minimum depths for embedment of vertical hooked stirrups.

## 170. Example of Slab or Rectangular-Beam Design

a. Problem. What slab depth and reinforcing are nceded for a span of 10 feet, live load of 500 pounds per square foot, using 2,000 pound concrete and Besscmer stecl reinforcing good for 18,000 pounds per square inch?
b. Solution:
(1) $n=30,000 \div 2000=15$ (par. 164e)
(2) $f_{c}=2000 \times 0.45=900 \mathrm{psi}($ par. $164 c)$
(3) $b=12$ inches (section of slab 1 foot wide)
(4) Assume 8 -inch slab thickncss (normally 0.8 inch per foot of span)
(5) Total load $=500+(8 / 12 \times 150)=600$ pounds per square foot
(6) $\cdot M=1 / 8 \mathrm{Wl}=1 / 8(600 \times 10)(10 \times 12)=90,000$ inch-pounds
(7) $K=165.3 ; j=0.857 ; p=0.0107$ (par. 167b)
(8) $d=\sqrt{\frac{M}{b k}}=\sqrt{\frac{90,000}{12 \times 165.3}}=6.7$; use 8 inches
(9) $A_{\mathrm{g}}=p b d=0.0107 \times 12 \times 6.7=0.86$ square inch. Adopt \#6 bars spaced 6 inches c.-to-c., area $=0.88$ square inches per foot of width.
c. Example (Vertical Stirrups, Triangular Shear Diagram). Given:
 Max. $v^{\prime} \doteq 108 \mathrm{psi} ;$ $S=8 \mathrm{ft} .3 \mathrm{in}$;
$b=13$ in.; $d \doteq 20 \mathrm{in}$.;
$f_{0}=20,000 \mathrm{psi} ;$
$f^{\prime}{ }_{c}=3,000 \mathrm{psi}$;
No. 3 U-stirrups.
(scale marks are $1-\mathrm{mm}$ each)
From figure $82-B$; for $f_{v}=20,000$ and No. 3 U-stirrups: $A_{v} f_{0}=4,400$; and $B=1$ for vertical stirrups.

$$
\frac{v^{\prime} b}{B A_{v} f_{v}}=\frac{108 \times 13}{4,400}=0.319 .
$$

On figure $82-B$, place a straightedge connecting the values of $S$ and $\frac{v^{\prime} b}{B A_{\imath} f_{0}}=$ and read the spacing of stirrups where their respective heavy lines cross the straightedge. In case the spacing is grcater than the maximum allowable spacing of $\frac{12}{2} d$, use the last spacing permitted until distance $S$ is reached.
Read: 3 at 3 in., 5 at 4 in., 2 at 5 in., 2 at 6 in., 1 at 8 in., 4 at 10 in. Total number of stirrups: $N=17$.
Refer to figure $82(3)$ for No. 3 stirrups with $f^{\prime}{ }_{c}=3,000 \mathrm{psi}$ and $f_{0}=$ $20,000 \mathrm{psi}$ and ascertain that stirrups have sufficient embedment;
$d=10.9 \mathrm{in}$. required. If it is desired to locate the first stirrup at half the initial spacing from the end of beam, the $\frac{v^{\prime} b}{B A_{v} f_{v}}$ curve should be shifted horizontally a distance equal to half the initial stirrup spacing.
d. Inclined Stirrups. They are proportioned by the formula -

$$
A_{v}=\frac{V^{\prime} s}{f_{v} j d(\sin \alpha+\cos \alpha)}
$$

Where $\alpha=$ angle between stirrups and axis of beam.
e. Limitation. Stirrups placed perpendicular to the longitudinal reinforcement must not be used alone as web reinforcement when the shearing unit stress ( $v$ ) exceeds $0.08 f^{\prime}$ cor 240 pounds per square inch.

## 171. Example of T-Beam Design

a. Problem. Design a T-beam for a clear span of 20 feet, slab thickness of 5 inches; total load from slab 400 pounds per square foot, beam spacing 9 feet center to center, 3,000-pound concrete, allowable stress in steel 20,000 pounds per square inch.
b. Solution.
(1) $n=30,000 \div 3,000=10$ (par. 164e)
(2) $f_{c}=3,000 \times 0.45=1,350 \mathrm{psi}$ (par. 164c)
(3) $b=60$ inches ( $1 / 4$ span length controls (par. 168a)
(4) Assume $b^{\prime}=15$ inches (trial and error)
(5) Assume $d=13$ inches (trial and error)
(6) $\frac{t}{d}=\frac{5}{13}=.38$
(7) $K=234 ; p=0.0135$ (par. $168 c$ )
(8) Weight of stem $=\frac{12 \times 15}{144} \times 150=188$ pounds per foot
(9) Total load $=9 \times 400+188=3,788$ pounds per foot
(10) $M=1 / 8 W L=1 / 8 \times 3,788 \times 20 \times 20 \times 12=2,272,800$ inch-pounds
(11) $d=\sqrt{\frac{M}{b K}}=\sqrt{\frac{2,272,800}{60 \times 234}}=12.7$ inches
(12) $A_{s}=p b d=0.0135 \times 60 \times 12.7=10.2$ square inclies. Adopt four \#11 square bars and four \#9 square bars: total area 10.24 square inches (par. 165b).
(13) Required $b^{\prime}=13 \times 1 \frac{114}{4}=161 / 4$ inches. Adopt 16 inches (required for four $1 \frac{1}{4}$-inch bars in one layer, figure 81)
(14) Total depth of stem below slab $=13 \frac{1}{2}+1 / 2+5 / 8+\left(2 \times 1 \frac{1}{4}\right)-5$ $=12 \frac{1}{8}$ inches. Adopt 12 inches.
(15) Design of stirrups-
(a) Revised weight-

Load from slab- $400 \mathrm{psf} \times 9 \mathrm{ft}=3,600 \mathrm{lbs}$.
Stem below slab $-\frac{12 \times 16}{144} \times 150=\frac{200 \mathrm{lbs} .}{3,800 \mathrm{lbs} / \mathrm{ft}}$
(b) $\cdot V=\frac{1}{2} \times 3,800 \times 20=38,000 \mathrm{lbs}$.
(c) $v=\frac{V}{b \times j \times d} \cdot \quad b^{\prime}=16^{\prime \prime} . \quad d=13^{\prime \prime}$.

1. $t / d=0.38$
2. $K=\frac{\frac{n A_{s}}{b t}+\frac{1}{2} \times t / d}{\frac{n A_{s}}{b t}+1}=\frac{\frac{10 \times 10.24}{60 \times 5}+\frac{1}{2} \times 0.38}{\frac{10 \times 10.24}{60 \times 5}+1}=0.398$
3. With $t / d=0.38$ and $k=0.398$, cnter figure $82(1)$ and determine $j=0.87=210$ pounds per square inch.
(d) Then $v=\frac{38,000}{16 \times 0.87 \times 13}$
(e) $v_{c}=0.03 \times 3,000=90 \mathrm{psi}$
(f) $v^{\prime}=210-90=120 \mathrm{psi}$
(g) From figure $82(2)$ for $f_{0}=20,000 \mathrm{psi}$ and \#3 U-stirrups, $A_{0} f_{0}=4,400$ and $B=1$ for vertical stirrups, then-
$\frac{v^{\prime} b}{B A_{v} f_{v}}=\frac{120 \times 16}{1 \times 4,400}=0.436$
(h) $S=\frac{120 \times 10}{210}=5.71^{\prime}$
(i) Enter figure 82-B for$\frac{v^{\prime} b}{B A_{r} f_{0}}=0.436$ along left side and $S=5.71^{\prime}$ along the bottom, choose stirrups as follows-
8 at $3^{\prime \prime}, 2$ at $4^{\prime \prime}, 2$ at $5^{\prime \prime}, 5$ at $6^{\prime \prime}$. (This carries the stirrups past the point where they are required. It should be noted here that, according to figure $82(2)$, we could have used $8^{\prime \prime}, 9^{\prime \prime}$, and $10^{\prime \prime}$ spacing, but we are limited to $1 / 2 d$ as a maximum.)

## 172. Retaining Walls

For avcrage carth pressures and for licights up to 10 feet, cross sections of plain concrete and reinforced concrete are given in figure 83.

## Section V. TIMBER

## 173. Working Stresses

Table 176 shows the allowable unit stresses for stress-grade lumber of certain species and grades. The figures are for normal loading conditons and for pcacetime civilian or equivalent military construction. For temporary structures, and for military construction in a theater of operations, the stresses given in the table may be increascd by a maximum of 50 percent.



Figure 88. Concreteretaining walls.

Table 176. Allowable Unit Stresses-Stress-Grade Lumber

| Species and commercial grade a |  | Rules under which graded | Allowable unit stresses in pounds per square inch |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Extreme fiber in bending (f) and tension parallel to grain (t) ${ }^{\circ}$ | Horizontal shear (H) | Compression perpendicular to grain (cl) | $\begin{gathered} \text { Compres- } \\ \text { sion } \\ \text { parallel } \\ \text { to grain } \\ \text { (e) } \end{gathered}$ | Modulus of elastieity (E) |
| Ash, white: |  |  | National Hardwood Lumber Association. |  |  |  |  |  |
| 2150 f grade. | J. \& P $\mathrm{P}_{\text {------- }}$ | 2, 150 |  | 145 | 600 | 1, 700 | 1,650, 000 |
| 1900 f grade. | J. \& P.-B. \& S ${ }_{-}$ | 1, 900 |  | 145 | 600 | 1, 500 | 1, 650, 000 |
| 1700 f grade | J. \& P.-B. \& S $S_{-}$ | 1,700 |  | 145 | 600 | 1, 325 | 1, 650, 000 |
| 1450 f grade | J. \& P.-B. \& S.- | 1, 450 |  | 120 | 600 | 1, 150 | 1, 650, 000 |
| 1300 f grade | B. \& S | 1, 300 |  | 120 | 600 | 1, 050 | 1,650,000 |
| 1450 c grade | P. \& T |  |  |  | 600 | 1, 450 | 1, 650, 000 |
| 1200 c grade. | P. \& T |  |  |  | 600 | 1, 200 | 1,650, 000 |
| 1075 c grade. | P. \& T |  |  |  | 600 | 1, 075 | 1, 650, 000 |
| Beech: Birch: |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 2150 f grade | J. \& P -------- | National 1Tardwood Lumber Association. | 2, 150 | 145 | 600 | 1, 750 | 1, 760, 000 |
| 1900 f grade -----.------- | J. \& P.-B. \& S - |  | 1,900 | 145 | 600 | 1,525 | 1, 760, 000 |
| 1700 f grade.------------ | J. \& P.-B. \& S - |  | 1,700 | 145 | 600 | 1, 350 | 1, 760, 000 |
| 1450 f grade.------------- | J. \& P.-B. \& S |  | 1, 450 | 120 | 600 | 1, 150 | 1, 760, 000 |
| 1550 c grade | P \& T-.------- |  | ------ |  | 600 | 1,550 | 1,760,000 |
| 1450 c grade------------- | P \& T--------- |  | ------ | ------- | 600 | 1, 450 | 1, 760, 000 |
| 1200 c grade.------------ | P\& T--------- |  |  |  | 600 | 1, 200 | 1, 760, 000 |


| Chestnut: <br> 1450 f grade $\qquad$ <br> 1200 f grade $\qquad$ <br> 1075 c gradc. $\qquad$ | $\begin{aligned} & \text { J. \& P } \\ & \text { J. \& P.-B. \& S. } \\ & \text { P. \& T- } \end{aligned}$ | National Hardwood Lumber Association. | 1,450 1, 200 | 120 120 | $\begin{aligned} & 360 \\ & 360 \\ & 360 \end{aligned}$ | $\begin{array}{r} 1,200 \\ 950 \\ 1,075 \end{array}$ | $\begin{aligned} & 1,100,000 \\ & 1,100,000 \\ & 1,100,000 \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Cypress, southern, coast type (tidewater red): |  |  |  |  |  |  |  |
| 1700 f grade. | J. \& P.-B. \& S ${ }_{-}$ | Southern Cypress Manu- | 1, 700 | 145 | 360 | 1,425 | 1, 320, 000 |
| 1300 f grade. | J. \& 1.-B. \& S ${ }_{-}$ | facturers' Association. | 1,300 | 120 | 360 | 1, 125 | 1, 320, 000 |
| 1450 e grade | P. \& T |  |  |  | 360 | 1,450 | 1, 320, 000 |
| 1200 c grade_ | 1. \& T |  |  |  | 360 | 1,200 | 1, 320, 000 |
| Cypress, southern, inland type: | J \& 13-13 \& |  | 1,700 | 145 | 360 | 1,425 | 1,320,000 |
|  | J. \& P.-B. \& S_ | National Hardwood | 1,700 | 145 | 360 | 1,425 | 1, 320,000 |
| 1300 f grade | J. \& P.-B. \& S - | Lumber Association. | 1,300 | 120 | 360 | 1, 125 | 1, 320, 000 |
| 1450 c grade | P. \& T------ |  |  |  | 360 | 1,450 | 1, 320, 000 |
| 1200 c grade | P. \& T |  |  |  | 360 | 1,200 | 1, 320, 000 |
| Douglas fir, coast region: |  |  |  |  |  |  |  |
| Dense select structural | LF-...-.------ |  | 2, 050 | cif 120 | 455 | 1,500 | 1, 760, 000 |
| Select structural | LF |  | 1,900 | e: b 120 | 415 | 1,400 | 1, 760, 000 |
| 1500 f industrial | LF |  | 1,500 | 120 | 390 | 1,200 | 1, 760, 000 |
| 1200 f industrial | LF |  | 1,200 | 95 | 390 | 1,000 | 1, 760,000 |
| Dense selcet structural ${ }^{\mathbf{t}}$ | J. \& P | Inspection Bureau. | 2, 050 | cf ${ }^{\text {f }} 120$ | 455 | 1,650 | 1, 760,000 |
| Select structural. | J. \& P |  | 1,900 | cif 120 | 415 | 1,500 | 1, 760, 000 |
| Dense construction ${ }^{\text {b }}$ | J. \& P |  | 1,750 | ext 120 | 455 | 1,400 | 1, 760, 000 |
| Construction. | J. \& P |  | 1,500 | e g t 120 | 390 | 1,200 | 1, 760, 000 |
| Standard. | J. \& P |  | 1,200 | - ह b 95 | 390 | 1,000 | ${ }^{\text {j }} 1,760,000$ |


| Species and commercial grade a |  | Rules under which graded | Allowable unit stresses in pounds per square ineh |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Extreme fiber in bending (f) and tension parallel to grain (t) | $\begin{aligned} & \text { Horizontal } \\ & \text { shear } \\ & \text { (H) } \end{aligned}$ | Compression perpendicular (cl) <br> (cl) | Compres. sion parallel to grain (c) | Modulus of elasticity (E) |
| Douglas fir, coast region-Con. |  |  | West Coast Lumber Inspection Bureau. |  |  |  |  |  |
| Dense select structural b_ | B. \& S | 2, 050 |  | ${ }^{\text {i }} 120$ | 455 | 1, 500 | 1, 760,000 |
| Select structural | B. \& S | 1,900 |  | ; 120 | 415 | 1, 400 | 1, 760, 000 |
| Dense construction b | B. \& S | 1,750 |  | ; 120 | 455 | 1, 200 | 1,760,000 |
| Construction. | B. \& S | 1,500 |  | ${ }^{\text {i }} 120$ | 390 | 1,000 | 1, 760,000 |
| Dense select structural b | P. \& T | 1,900 |  | i 120 | 455 | 1,650 | 1, 760, 000 |
| Select structural_ | P. \& T | 1, 750 |  | ${ }^{\text {i }} 120$ | 415 | 1, 500 | 1, 760, 000 |
| Dense construction ${ }^{\text {b }}$ | P. \& T | 1,500 |  | i 120 | 455 | 1, 400 | 1, 760, 000 |
| Construction | P. \& T | 1,200 |  | ; 120 | 390 | 1, 200 | 1, 760, 000 |
| Douglas fir, inland region: |  | Western Pine Association. |  |  |  |  |  |
| Select structural ${ }^{\text {b }}$-- | J. \& P. ${ }^{\text {d }}$ |  | 2, 150 | 145 | 455 | 1, 750 | 1, 760, 000 |
| Structural. - | J. \& P.d |  | 1, 900 | 100 | 400 | 1, 400 | 1, 650, 000 |
| Common structural | J. \& P.d |  | 1, 450 | 95 | 380 | 1,250 | 1, 650, 000 |
| Select structural ${ }^{\text {b }}$. | P. \& T |  | ----- |  | 455 | 1, 750 | 1, 760, 000 |
| Structural.- | P. \& T |  |  |  | 400 | 1, 400 | 1,650,000 |
| Common structural. | P. \& T |  |  |  | 380 | 1, 250 | 1, 650, 000 |



See footnotes at end of tablo.

| Species and commercial grade a |  | Rules under whieh graded | Allowable unit stresses in pounds per square inch |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Extreme fiber in bending (f) and tension parallel to grain (t) ${ }^{0}$ | $\begin{aligned} & \text { Horizontal } \\ & \text { slearar } \\ & \text { (H) } \end{aligned}$ | Compression perpendicular to grain (cl) | Compression parallel to grain (c) | Modulus of clasticity (E) |
| Hemlock: West Coast-Con. Construction. | B. \& S--------- |  | West Coast Lumber Inspection Burcau. | 1,500 | ${ }^{\text {m }} 100$ | 365 | 1,000 | 1,540, 000 |
| Construction.- | P. \& T | 1,200 |  | ${ }^{\text {m }} 100$ | 365 | 1, 100 | 1,540, 000 |
| Hickory, Pecan: |  | National Hardwood Lumber Association. |  |  |  |  |  |
| 2150 f grade | J. \& P.-B. \& S - |  | 2, 150 | 145 | 720 | 1, 725 | 1, 980, 000 |
| 1900 f grade | J. \& P.-B. \& S - |  | 1,900 | 145 | 720 | 1, 550 | 1,980, 000 |
| 1700 f grade | J. \& P.-B. \& S - |  | 1,700 | 145 | 720 | 1,350. | 1,980,000 |
| 1550 c grade. | P. \& T-------- |  | ------ | ------- | 720 | 1, 550 | 1,980, 000 |
| 1450 c grade. | P. \& T. |  |  | -------- | 720 | 1, 450 | 1,980, 000 |
| 1325 c grade. | P. \& T |  |  |  | 720 | 1,325 | 1,980, 000 |
| Larch: |  | Western Pine Association. |  |  |  |  | - |
| Selcet structural ${ }^{\text {b }}$ | J. \& P.d.------ |  | 2, 150 | 145 | 455 | 1, 750 | 1, 650, 000 |
| Structural----- | J. \& P. ${ }^{\text {d }}$------- |  | 1,900 | 120 | 415 | 1, 450 | 1,650,000 |
| Common structural. | J. \& P.d |  | 1, 4.50 | 120 | 390 | 1,325 | 1,650,000 |
| Selcet structural ${ }^{\text {b }}$ | P. \& T |  |  |  | 455 | 1, 750 | 1, 650, 000 |
| Structural. | P. \& $\mathbf{T}_{--\ldots-\ldots-}$ |  |  | ------- | 415 | 1, 450 | 1,650, 000 |
| Common structural. | P. \& T |  |  |  | 390 | 1, 325 | 1,650,000 |



See footnutes at end of table.

| Species and commercial grade a |  | Rules under which graded | Allowable unlt stresses in pounds per square inelı |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Extrerne fiber in bending (f) and tension parallel to grain (t) ${ }^{\circ}$ | $\begin{aligned} & \text { Horizontal } \\ & \text { sliear } \\ & \text { (H) } \end{aligned}$ | Compression perpendicular to grain (cl) | Compression parailel to grail <br> (c) | Modulus of clasticity (E) |
| Pine, southern-Continued ${ }^{\circ}$ |  |  |  |  |  |  |  |  |
| Dense structural 86. ${ }^{\text {b }}$. |  | Southern Pine Inspection | 2,900 | 150 | 455 | 2, 200 | 1, 760,000 |
| Dense structural 72.b r |  | Bureau. | 2,350 | 135 | 455 | 1,800 | 1, 760, 000 |
| Dense structural 65.b r |  |  | 2, 050 | 120 | 455 | 1, 600 | 1, 760, 000 |
| Dense structural 58.b r | 3 inches and 4 |  | 1,750 | 105 | 455 | 1, 450 | 1, 760, 000 |
| No. 1 dense SR ${ }^{\text {b }}$ r | inches thick. |  | 1, 750 | 120 | 455 | 1, 750 | 1, 760, 000 |
| No. 1 SR. |  |  | 1, 500 | 120 | 390 | 1,500 | 1, 760, 000 |
| No. 2 dense SR ${ }^{\text {b }}$ |  |  | 1,400 | 105 | 455 | 1, 050 | 1, 760, 000 |
| No. 2 SR . |  |  | 1,200 | 105 | 390 | 900 | 1, 760, 000 |
| Dense structural $86{ }^{\text {b r }}$ |  |  | ${ }^{\text { 2 , }} 400$ | 150 | 455 | 1, 800 | 1, 760, 000 |
| Dense structural 72 b r | 5 inches thick |  | - 2, 000 | 135 | 455 | 1,550 | 1, 760, 000 |
| Dense structural $65{ }^{\text {b r }}$ | and up. |  | ${ }^{\text {p }} 1,800$ | 120 | 455 | 1, 400 | 1, 760, 000 |
| Dense structural $58{ }^{\text {b r }}$ - |  |  | - 1, 600 | 105 | 455 | 1, 300 | 1, 760, 000 |
| No. 1 dense SR ${ }^{\text {b }}{ }_{\text {r }}$ - |  |  | - 1, 600 | 120 | 455 | 1,500 | 1, 760, 000 |
| No. 1 SR-- |  |  | - 1, 400 | 120 | 390 | 1,300 | 1, 760, 000 |
| No. 2 dense SR ${ }^{\text {b r }}$-- |  |  | - 1, 400 | 105 | 455 | - 1,050 | 1, 760, 000 |
| No. 2 SR.--------- |  |  | - 1, 200 | 105 | 390 | 900 | 1, 760, 000 |



[^40]Table 176. Allowable Unit Stresses--Stress-Grade Lumber-Continued

 J. \& P . $=$ joists and planks. B. \& S. $=$ beams and stringers. I . \& $\mathrm{K}^{\prime}$. $=$ posis and timhers. $\mathrm{I}, \mathrm{F}=$ light framing. $\quad \mathrm{KD}=$ sect note $\mathrm{q} . \quad \mathrm{SR}=$ sliress mater.
b Fhese grades neet the requirement for density.

- In tension memhers the slope of grain linttations applicable to the middle portion of the length of the joist-and-plank and beam-and-stringer grades used shall apply thronghout the length of the piece.
d'The allowate unil stresses for tension parallel to grain (t) and for compression parallel to grain (e) given for these jolst-and-plank and beam-and-stringer grades are applicable when the followling addilional provisions are applied to the gradus; the sum of the sizes of all knots in any 6 inehes of the length of the piece shall not exeeed twice the maximum permissible slze of knot; two knots of maxlmum permissible size shall not be withln the same 6 inehes of length of any face.
e Value applies to pleces used as planks.
1 Value applles to 2 -inch-thiek pleces of select structural grade used ${ }^{1}$ as jolsts.
e For 2-ineh-thlek pieces of construction and standard grades used as jotsts:
$H=120$ when length of splt is approximately equal to one-balf the wldth of plece.
$\Pi=100$ when length of split is approximately equal to the width of piece.
$H=70$ when length of split is approxlmately cqual to $11 / 2$ times width of plece.
${ }^{\text {b }}$ For 3 -inch-thlek pleces of select struetural, eonstructlon, and standard grades used as jolsts:
$\mathrm{II}=120$ when length of spllt is approximately $21 / 4$ inches
$H=80$ when length of split is approxlmately $41 / 2$ Inches, and for $4 \cdot$ Ineh-thlek picees of select structural, construction, and standard grade used as jolsts'
$\mathrm{H}=120$ when length of spllt is approximately 3 Inches.
$\mathrm{H}=80$ when length of split is approximately 6 inches.
${ }^{i}$ For beams and stringers and for posts and timbers.
$\mathrm{H}=120$ when length of split is equal to one-half the nominal narrow face dlmenslon.
$\mathrm{H}=100$ when length of spllt is equal to the nominal narrow face dimenslon.
$\mathrm{H}=80$ when length of split ls equal to $11 / 2$ thes the nominal narrow face dimenslon.
; Pieees of less than medium grain, when lneloded in the grade of STANDARD may be consldered as having a modulus of elastlcity (E) of $1,320,000$.
$\mathbf{k}$ For 2-inch-thick pleees of construetlon and standard grades used as joists:
$\mathrm{H}=100$ when length of split is approximately equal to one-half the width of picce.
$\mathrm{H}=80$ when length of spllt is approximately equal to the width of plece.
$\mathrm{H}=60$ when length of spllt is approximately equal to $1 \frac{1}{2}$ tlmes the width of plece.

IFor 3-inch thick phees of select stituetme:n, constrmetion, and standard grades used as joists:
$11=10)$ when lenrth of split is approvimately $21 / 4$ inches.
$1 \Gamma=70$ when length of split is approximately $41 / 2$ inches, and for 4 -inch-thick pirees of select.structural, construction, and standardgrades used as joists
$\mathrm{H}=100 \mathrm{when}$ length of split is approvimately 3 inches.
$1 \Gamma=70$ when length of split is approximately 6 inches.
$m$ For beains and stringers and for posts and timbers:
$11=100$ when length of split is equal to $3 / 4$ the nominal narrow face dimension.
$\Pi=90$ when length of split is equal to the nominal narrow face dimension.
$\mathrm{II}=70$ when length of spltt is equal to $11 / 2$ tlmes the nominal narrow faee dimenslon.

- These grades applicable to 2 -inch tblekness only.
- All stress grades under the 1956 grading rules are all-purpose grades and apply to all sizes. Pieces so graded may be cut to shorter lengths wlthout impairment of the stress rating of the shorter pieces. Grade restrictlons provided by the 1956 grading rules apply to the entire length of the piece, and each piece is suitable for use in continuous spans, over double spans, or under concentrated loads without regrading for special shear or other special stress requirements. The following varlations apply to the provislons of paragraph 202-B for lumber ln service under wet eonditions or where the molsture content is at or above fiber saturatlon point, as when contlnuously submerged: (1) the allowable unlt stresses in bending, tension parallel to grain, and horizontal shear shall he limited in all thicknesses to the stresses Indicated for thicknesses of 5 Inches and up; (2) the allowahle unit stresses for eompresslon parallel to grain shall be limited to the stresses indleated for thicknesses of 5 Inches and up reduced by 10 percent; (3) the allowable unit stresses for compression perpendicular to grain shall be reduced onethird; and (4) the values for modulus of elasticity shall be redueed by one-cleventh.
p These stresses apply for loadlng either on narrow face or on wide face, whlch is an exceptlon to pars. $102-\mathrm{B}-1$ and $205-\mathrm{B}$.
- KD=kiln dried in aeeordance with the provislons of pars. 219 and 220 of the 1956 grading rules.
r Longleaf may be speclfied by substitutlng "longleaf" for "dense" in the grade name, and when so specified the same allowable stresses shall apply.

Values for lengths of split other than those given in $\mathbf{s}, \mathbf{h}$, and ${ }^{\mathbf{i}}$ are proportionate.
Values for lengths of splits other than those given in $\mathbf{k}, \mathbf{I}$, and $\pm$ are proportionate.
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## 174. Dimensions and Properties

Table 177 is an abridged list of American standard dressed sizes of dimension lumber, with moments of inertia and section moduli. It is assumed that the greater dimension of cross section ( $=h$ ) is vertical.

Table 177. Dressed Sizes of Lumber

| Nominal size | American standar | $\begin{aligned} & \text { Area of section } \\ & \text { sq in. } \end{aligned}$ | $\mathrm{I}=\frac{\mathrm{bh}}{}{ }^{12}$ | $\mathrm{S}=\frac{\mathrm{bh}{ }^{2}}{6}$ |
| :---: | :---: | :---: | :---: | :---: |
|  |  | In. ${ }^{2}$ | In. ${ }^{4}$ | In. ${ }^{3}$ |
| $1 \times 3$ | 25/32 $\times 258$ | 2.05 | 1. 18 | 0. 90 |
| $1 \times 4$ | 25/32 $\times 35$ | 2. 83 | 3. 10 | 1. 71 |
| $1 \times 6$ | 25/32 $\times 5$ \% | 4. 39 | 11. 59 | 4. 12 |
| $1 \times 8$ | $25 / 32 \times 71 / 2$ | 5. 86 | 27. 47 | 7. 32 |
| $1 \times 10$ | $25 / 32 \times 91 / 2$ | 7. 42 | 55. 82 | 11. 75 |
| $1 \times 12$ | 25/32 $\times 111 / 2$ | 8. 98 | 99.02 | 17. 22 |
| $2 \times 4$ | $13 / 8 \times 35 / 8$ | 5. 89 | 6. 45 | 3. 56 |
| $2 \times 6$ | 15/8x $5 \%$ | 9.14 | 24. 10 | 8. 57 |
| $2 \times 8$ | 15/8 $\times 71 / 2$ | 12. 19 | 57. 13 | 15. 23 |
| $2 \times 10$ | $15 / 8 \times 91 / 2$ | 15. 44 | 116. 10 | 24. 44 |
| $2 \times 12$ | $15 / 8 \times 111 / 2$ | 18. 69 | 205. 95 | 35. 82 |
| $3 \times 8$ | $25 / 8 \times 71 / 2$ | 19. 69 | 92. 29 | 24. 61 |
| $3 \times 10$ | $25 / 8 \times 91 / 2$ | 24. 94 | 187.55 | 39. 48 |
| $3 \times 12$ | $25 / 8 \times 11 / 1 / 2$ | 30. 19 | 332.69 | 57.86 |
| $4 \times 12$ | $35 / 8 \times 111 / 2$ | 41. 69 | 459. 43 | 79. 90 |
| $4 \times 16$ | $35 / 8 \times 151 / 2$ | 56. 19 | 1, 124. 92 | 145. 15 |
| $6 \times 12$ | $51 / 2 \times 111 / 2$ | 63. 25 | 697.07 | 121. 23 |
| $6 \times 16$ | $51 / 2 \times 151 / 2$ | 85. 25 | 1, 706.78 | 220. 23 |
| $6 \times 18$ | $51 / 2 \times 171 / 2$ | 96. 25 | 2, 456. 38 | 280.73 |
| $8 \times 16$ | $71 / 2 \times 151 / 2$ | 116. 25 | 2, 327. 42 | 300.31 |
| $8 \times 20$ | $71 / 2 \times 191 / 2$ | 146. 25 | 4, 634. 30 | 475. 31 |
| $8 \times 24$ | $71 / 2 \times 231 / 2$ | 176. 25 | 8, 111. 17 | 690. 31 |

## 175. Beam Design

$a$. Timber beams are designed using the beam formulas in paragraph 146 and the unit stresses in paragraph 173. For beams in which flexure controls, table 178 is used.
$b$. If deflection is the controlling factor or is limited to $/ / 360$ span (the usual requirement where plastered ceilings occur), use the deflection formulas in paragraph 133. For the beam in the example of table 160, carrying its full load of 20,300 pounds-

$$
\text { Deflection }=\frac{5 \mathrm{w} 1^{4}}{384 \mathrm{E} 1}=\frac{4 \times 20,300 \times(16 \times 12)^{3}}{384 \times 1,760,000 \times 1,540}=0.69 \text { inch }
$$

Allowable deflection $=\frac{12 \times 16}{360}=0.53$ inch

Table 178. Timber Beams Loads

| $\mathrm{Span}_{\substack{\text { (t.) }}}$ | Safe loads in pounds uniformly distributed for rectangular beams per inch of widlh (For allowable fiber stress of 1,000 p.s.i.) |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Nominal depth of beam (in.) |  |  |  |  |  |  |  |  |  |  |
|  | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 4 | 370 | 880 | 1, 560 | 2, 510 | 3, 670 | 5, 060 |  |  |  |  |  |
| 6. | 240 | 590 | 1, 040 | 1, 670 | 2, 450 | 3, 380 |  |  |  |  |  |
| 8. | 180 | 440 | 780 | 1, 260 | 1, 840 | 2,530 |  |  |  |  |  |
| 10 | 150 | 350 | 630 | 1, 000 | 1, 470 | 2, 020 | 2, 670 | 3, 400 | 4, 220 | 5, 140 | 6, 140 |
| 12 | 120 | 290 | 520 | 840 | 1, 220 | 1, 690 | 2, 220 | 2, 840 | 3, 520 | 4, 280 | 5, 110 |
| 14 | 100 | 250 | 450 | 720 | 1, 050 | 1, 450 | 1, 900 | 2, 430 | 3, 020 | 3, 660 | 4, 380 |
| 16 | 90 | 220 | 390 | 630 | 920 | 1, 260 | 1, 670 | 2, 120 | 2, 640 | 3, 220 | 3, 840 |
| 18 | 80 | 200 | 350 | 560 | 820 | 1, 120 | 1, 480 | 1, 890 | 2, 340 | 2, 860 | 3, 400 |
| 20 | 70 | 180 | 310 | 500 | 730 | 1, 010 | 1, 330 | 1,700 | 2, 110 | 2, 570 | 3, 060 |
| 22 |  | 160 | 280 | 460 | 670 | 920 | 1,210 | 1, 540 | 1, 920 | 2, 340 | 2, 790 |
| 24 |  | 150 | 260 | 420 | 610 | 840 | 1, 110 | 1, 420 | 1, 760 | 2, 140 | 2,560 |
| 26 |  | 140 | 240 | 390 | 560 | 780 | 1, 030 | 1, 310 | 1, 620 | 1,980 | 2, 360 |
| 28. |  | 130 | 220 | 360 | 530 | 720 | 950 | 1, 210 | 1, 510 | 1, 830 | 2, 190 |
| 30 |  | 120 | 210 | 330 | 490 | 670 | 890 | 1, 130 | 1, 410 | 1, 710 | 2, 040 |
| 32. |  | 110 | 200 | 310 | 460 | 630 | 830 | 1, 060 | 1, 320 | 1, 610 | 1,920 |
| 34. |  | 100 | 180 | 290 | 430 | 590 | 780 | 1, 000 | 1, 240 | 1,510 | 1, 810 |
|  |  |  |  |  |  |  |  |  |  |  |  |

For fiber strcsses other than 1,000 pounds per square inch, change safe loads proportionately.
Example. a. Problem. What is the safe uniformly distributcd load on a beam 8 inches by 14 inches of select structural Douglas fir, inland region, on a 16 -foot span?
b. Solution. From par. 173, the fiber stress is 2,150 pounds persquare inch. From the table above, the safe load at 1,000 pounds per square inch is 1,260 pounds per inch of width. The actual width of an 8inch surfaced timber is $7 \frac{1}{2}$ inches. The safe lond is then

$$
7 \nLeftarrow 2 \times 1,260 \frac{2,150}{1,000}=20,300 \text { pounds }
$$

At 35 pounds per cubic foot the beam weighs about 435 pounds. This is about- $2 \frac{1}{2}$ percent of the total safe load and normally can be neglected.

To hold deflection to $1 / 360$ of the span for building design, the load is reduced to $53 \% 9$ of 20,300 or 15,600 pounds, or a deeper beam is selected.
c. Horizontal shear is likely to be the controlling factor in the safe loads for relatively short beams loaded to full flexural strength; it rarely affects the design of longer beams. Safe loads are given in table 179.

Table 179. Safe Loads for Short Beams

| Safe loads in pounds uniformly distributed for reetangular beams, per inch of width (For allowable horizontal shear of 100 pounds per square Inch) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Depth (inches) | Safe load (pounds) | Depth (inches) | Safe load (pounds) | Depth (inehes) | Sate load (pounds) |
| 4 | 480 | 12 | 1,530 | 20 | 2, 600 |
| 6 | 750 | 14 | 1, 800 | 22 | 2, 870 |
| 8 | 1,000 | 16 | 2, 060 | 24 | 3, 130 |
| 10 | 1,260 | 18 | 2,330 |  |  |

For allowable stresses other than 100 pounds per square inch, change safe loads proportionately.
Example. Assume the 8 -inch by 14 -inch beam in the example in table 160 is used on a 10 -foot span. The allowable load due to flexure is-

$$
71 / 2 \times 2,020 \times \frac{2,150}{1,000}=32,600 \text { pounds }
$$

Allowable load due to horizontal shear (stress is given as 145 pounds per square inch in paragraph 161):

$$
71 / 2 \times 1,800 \times \frac{145}{100}=19,600 \text { pounds }
$$

In this case the shear controls the allowable load.

## 176. Column Design

a. The safe axial load for a wood column of square or rectangular cross section is given by the formula--

$$
P=A \frac{0.30 E}{(l / d)^{2}}
$$

Where $P=$ safe load in pounds
$A=$ cross-sectional area in square inches
$E=$ modulus of elasticity in psi
$l=$ length (height) of column, in inches
$d=$ dimension of the least side of the cross section, in inches.
(It is to be noted that, for dressed lumber, this is the actual dimension, not the nominal.)
In this formula, $\mathrm{P} / \mathrm{A}$ must not exceed c , the allowable unit stress in compression, parallel to grain, for the wood in question.

Table 180. Safe Loads-Dressed-Lumber Columns

| Nominal dimensions of cross sectlon (Inches) | Length (feet) | Safe load (kips) |
| :---: | :---: | :---: |
| 4 by 4 | $\left\{\begin{array}{r}6 \\ 8 \\ 10\end{array}\right.$ | $\begin{array}{r} 17.5 \\ 9.9 \\ 6.3 \end{array}$ |
| 4 by 6. | $\left\{\begin{array}{r}8 \\ 10 \\ 12\end{array}\right.$ | $\begin{array}{r} 15.3 \\ 9.8 \\ 6.8 \end{array}$ |
| 6 by 6 | $\left\{\begin{array}{r}8 \\ 10 \\ 12\end{array}\right.$ | $\begin{aligned} & 52.1 \\ & 33.6 \\ & 23.3 \end{aligned}$ |
|  | $\left\{\begin{array}{r}10 \\ 12 \\ 14 \\ 16\end{array}\right.$ | $\begin{aligned} & \text { 45. } 8 \\ & \text { 31. } 7 \\ & \text { 23. } 4 \\ & \text { 17. } 9 \end{aligned}$ |
| 8 by 8 | $\left\{\begin{array}{r}10 \\ 12 \\ 14 \\ 16\end{array}\right.$ | $\begin{array}{r} 116.0 \\ 80.5 \\ 59.2 \\ 45.3 \end{array}$ |
| 8 by $10 \ldots$ | $\left\{\begin{array}{r}10 \\ 12 \\ 14 \\ 16 \\ 18\end{array}\right.$ | 147. 0 <br> 102. 0 <br> 75.0 <br> 57. 4 <br> 45. 4 |
| 10 by 10 | $\left\{\begin{array}{r}10 \\ 12 \\ 14 \\ 16 \\ 18\end{array}\right.$ | $\begin{array}{r} 300.1 \\ 206.3 \\ 152.1 \\ 116.8 \\ 92.5 \end{array}$ |
| 8 by 12 | $\left\{\begin{array}{r}10 \\ 12 \\ 14 \\ 16 \\ 18\end{array}\right.$ | 178. 0 <br> 123. 5 <br> 90. 7 <br> 69. 5 <br> 55. 0 |
| 10 by 20 | $\left\{\begin{array}{c}12 \\ 14 \\ 16 \\ 18 \\ 20\end{array}\right.$ | 249. 7 <br> 184. 1 <br> 141. 4 <br> 112. 0 <br> 90.1 |
|  | $\left\{\begin{array}{r}12 \\ 14 \\ 16 \\ 18 \\ 20\end{array}\right.$ | 446. 7 <br> 327. 6 <br> 250. 3 <br> 197. 6 <br> 159. 9 |

$b$. Some representative values of safe loads in dressed-lumber columns are given in table 180, based on $E=1,760,000$, the accepted value for southern pine and coastal Douglas fir.

## 177. Connections in Wood Framing

In wood trusses and similar structures, sizes of members may be controlled by the thickness and width necessary for the design of connections which will transmit the stresses. Working loads for various fastenings are as follows:
a. Nails and Spikes. The safe lateral load for one nail or spike driven into the side grain of seasoned lumber so that at least twothirds of the length of the nail is in the wood member holding the point (reduce load 60 percent for nails in end grain and 25 percent for unseasoned wood) is as follows:
$900 \times \mathbf{D}^{3 / 2}$ for white pine and eastern hemlock
$1200 \times \mathrm{D}^{3 / 2}$ for Douglas fir and southern yellow pine $1700 \times \mathrm{D}^{3 / 2}$ for oak, ash, and hard maple
Where $\mathrm{D}=$ diameter of nail, in inches.
Table 181 shows various nail and spike sizes.
Table 181. Nail and Spike Sizes

|  | Size | $-\quad \begin{aligned} & \text { Length } \\ & -(\text { inches }) \end{aligned}$ | Gage | $\underset{\text { Diameter (D) }}{\substack{\text { Dines) }}}$ | D ${ }^{3} \mathbf{2}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Nails | 3d | 11/4 ${ }^{\prime \prime}$ | 14 | 0. 0800 | 0. 0226 |
|  | 4d | $11 / 2^{\prime \prime}$ | 121/2 | . 0985 | . 0309 |
|  | 6 d | $2^{\prime \prime}$ | 111/2 | . 1130 | . 0380 |
|  | 8d | 21/2' ${ }^{\prime \prime}$ | 101/4 | . 1314 | . 0476 |
|  | 10 d | $3^{\prime \prime}$ | 9 | . 1483 | . 0570 |
|  | 16 d | $31^{1 / 1}$ | 8 | . 1620 | . 0652 |
|  | 20d | $4^{\prime \prime}$ | 6 | . 1920 | . 0841 |
|  | 30 d | $412^{\prime \prime}$ | 5 | . 2070 | . 0942 |
|  | 40d | $5^{\prime \prime}$ | 4 | . 2253 | . 1066 |
|  | 60 d | $6^{\prime \prime}$ | 2 | . 2625 | . 1347 |
| Spikes | $\left\{\begin{array}{r}7 \prime \\ 8^{\prime \prime} \\ 9^{\prime \prime} \\ 10^{\prime \prime} \\ 12^{\prime \prime}\end{array}\right.$ | $7^{\prime \prime}$ | 5/16 ${ }^{\prime \prime}$ | $5 / 16^{\prime \prime}$ | 0. 1750 |
|  |  | $8^{\prime \prime}$ | $38^{\prime \prime}$ | $3 / 8^{\prime \prime}$ | . 2295 |
|  |  | $9^{\prime \prime}$ | $3 / 8^{\prime \prime}$ | $3 / 8^{\prime \prime}$ | . 2295 |
|  |  | $10^{\prime \prime}$ | 3/8' ${ }^{\prime \prime}$ | $3 / 8^{\prime \prime}$ | . 2295 |
|  |  | 12' ${ }^{\prime \prime}$ | $3 / 8^{\prime \prime}$ | $3 / 8^{\prime \prime}$ | . 2295 |

b. Wood Screws. The safe lateral load for one wood screw driven into the side grain of seasoned lumber to a penetration of at least seven times its diameter into the member receiving the point (reduce load 25 percent for end grain and 25 percent for unseasoned wood) is as follows:
$2100 \times \mathrm{D}^{2}$ for white pine and eastern hemlock $2700 \times \mathrm{D}^{2}$ for Douglas fir and southern yellow pine $4000 \times \mathrm{D}^{2}$ for oak, ash, and hard maple

Table 182. Wood Screw Diameters

|  | Diameter-D | D2 |
| :---: | :---: | :---: |
|  | Inches | Inches ${ }^{2}$ |
| 1/2 inch-No. 4 | 0.1105 | 0.0122 |
| 3/4 inch-No. 8 . | . 1631 | . 0266 |
| 1 inch-No. 10 | . 1894 | . 0359 |
| $11 / 2$ inch-No. 12 | 2158 | . 0466 |
| 2 inch-No. 14. | 2421 | . 0586 |
| 21/2 inch-No. 16. | 2684 | 0720 |
| 3 inch-No. 18. | 2947 | 0868 |

Wherc $\mathrm{D}=$ diameter of shank of screw, in inches.
Typical wood-screw diameters arc shown in table 182.
c. Lag Screws.
(1) The safe lateral load for one lag screw driven into the side grain of seasoncd lumber to a penetration of nine times the diameter into the member recciving the point and holding a cleat having a thickness of 3.5 times the screw diameter (reduce load 35 percent for end grain and 25 percent for unseasoned wood) is as follows: $1500 \times \mathrm{D}^{2}$ for white pine and eastern hemlock $1700 \times \mathrm{D}^{2}$ for Douglas fir and southern cypress $1900 \times \mathrm{D}^{2}$ for southern yellow pine and soft maple $2200 \times \mathrm{D}^{2}$ for oak, ash, and hard maple
Where $\mathrm{D}=$ diameter of shank, in inches.
(2) If the cleat thickncss is more or less than $31 / 2$ times the screw diameter, use percentages of safe loads as shown in figure 84.
(3) If the penetration of the lag screw into the member receiving the point is more than nine times the screw diameter; that is, if the unthreaded shank penetrates the members, the load may be increased by the percentages in figure 85, up to an increase of 39 percent for a penetration of 7 or more diametcrs of the shank.
d. Bolts.
(1) Basic stresses. The basic allowable working stresses for the design of bolted joints in various specics are shown in table 183.
(2) Stress reductions. The abovc basic stresses apply to the bearing area (bolt diameter times length of contact area) of a member in double shear; that is, a main tension member with metal splice plates on both faces or wood splice plates one-half the thickness of the main member, except that for tension member with wood splice plates the stress used is reduced by 20 percent. The basic stresses apply to seasoned


Figure 84. Lag screws: percentage of full load for various cleat thicknesses.
Table 183. Stresses in Bolted Joints

| Species group No. | Species | Basic stress, p. s. i. |  |
| :---: | :---: | :---: | :---: |
|  |  | Parallel with grain | Perpendicular to grain |
| 1 | White fir, eastern hemlock, white pine, sprucc_- | 960 | 180 |
| 2 | Red cedar, western hemlock, Norway pine. .-. - | 1, 200 | 240 |
| 3 | Douglas fir, redwood, southern yellow pine . . - | 1,560 | 280 |
| 4 | Aspen, basswood, poplar | 1, 110 | 210 |
| 5 |  | 1, 440 | 300 |
| 6 | White ash, beech, birch, maple, oak, walnut. - | 1,800 | 480 |

lumber, dry conditions, proper bolt spacing, and low L/D ratio (length of bolt contact $\div$ bolt diameter). Reductions for various conditions are made as follows:
(a) Bolt diameter. For loads perpendicular to the grain, the basic stresses are increased by the factors shown in table 184.
(b) $L / D$ ratio; stress parallel with grain. For loads parallel with the grain and for $\mathrm{L} / \mathrm{D}$ ratios more than 2, the basic stresses are shown in figure 86 for the six groups of species.


Figure 85. Lag screws: percentage of full load for penetration in excess of nine diameters.
(c) $L / D$ ratio; stress perpendicular to grain. For loads perpendicular to the grain, the strcsses are reduced as shown in figure 87.
(d) Exposure and seasoning. For joints exposed to the wcather, use 75 percent of values otherwise obtained; 67 percent if usually wet or damp; and 33 percent for green lumber allowed to season under load.
(3) Example. A main tension member 4 inches thick (actually $35 / 8$ ) of seasoned Douglas fir for use indoors, connected by four $3 / 4$-inch bolts through wood splice plates. Bcaring area, $3.625 \times 0.75$, is 2.72 square inches L/D ratio, $3.625 \div 0.75$, is 4.83 , for which (2)(b) above gives a unit strcss of 1370 for group 3. Reducing 20 percent for wood splice plates brings this to 1095 pounds per square inch. The allowable load is $1095 \times 2.72 \times 4$, or about 11,900 pounds.
.Table 184. Bolt Diameter Stress Factors

| Bolt diameter (inches) | Diameter factor | Bolt diameter (inches) | Diameter factor |
| :---: | :---: | :---: | :---: |
| 1/4. | 2. 50 | 11/4- | 1. 19 |
| 3/8 | 1. 95 | $11 / 2$ | 1. 14 |
| 12 | 1. 68 | 13/4 | 1. 10 |
| 5/8. | 1. 52 | 2. | 1. 07 |
| 3/4- | 1. 41 | 212. | 1. 03 |
| 7/8 | 1. 33 | 3 and over---------- | 1 |
| 1. | 1. 27 |  |  |

e. Timber Connectors.
(1) Types available. The types of timber connectors which are standard items of issue include the $21 / 2-$ and 4 -inch split ring and the 4 -inch toothed ring. The dcsign data below cover the split-ring connector, which is the type regularly used. It is installed quickly and accurately in a groove made by a cutter in a $3 / 4$-inch electric drill, whereas the toothed ring is embedded by drawing the timbers together with a bighstrength bolt with smooth thread and a ball-bearing washer, to be then replaced by the regular bolt. The 4 -inch toothedring connector has design values about 10 percent below those of the 4 -inch split ring. It is used in comparatively light construction or in isolated locations where a heavy-duty drill is not available. Bolt diameters are $1 / 2$ inch for $21 / 2$-inch rings; ${ }^{3 / 4}$ inch for 4 -inch rings. Plate washer sizes are 2 by 2 by $1 / 8$ inch and 3 by 3 by $3 / 16$ inch for $21 / 2-$ and 4 -inch rings, respectively.
(2) Species groups. The connector load groupings for various species of lumber of structural grades are as follows:

## Species

A.-.--- Dense Douglas fir, oak, and longleaf yellow pine.
B.-.---- Coastal Douglas fir, larch, and shortleaf yellow pine.
C.------ Cypress, western hemlock, Norway pine, and redwood.
(3) Edge and end distances. Minimum distances from center of connector to edges and end of members are shown in figures $88,89,90$, and 91.


Figure 86. Bolted joints: unit working stresses for loads parallel with grain.


Figure 87. Bolted joints: unit working stresses for loads perpendicular to grain.


Figure 88. Edge distance for $2 \not 212-$ inch split rings.


Figure 89. Edgc distance for 4 -inch split rings.

END DISTANCE (inches)


Figure 90. End distance for $2 \not 12$-inch split rings.


Figure 91. End distance for 4 -inch split rings.
(4) Spacing.
(a) For $2 \frac{1}{2}$-inch rings, $3 \frac{1}{2}$-inch spacing is minimum and permits applying 75 percent of the full loads given below. For full load and various angles of load to grain, spacings vary from $41 / 4$ inches perpendicular to grain for loads at $60^{\circ}$ to $90^{\circ}$ with the grain, to $6 \frac{3 / 4}{}$ inches parallel with the grain for loads parallel with the grain.
(b) For 4 -inch rings, the above values are: 5 -inch spacing for 75 percent loading varying to 6 -inch spacing perpendicular to grain and 9 -inch spacing parallel with grain for loads parallel with the grain.
(5) Allowable loads. For satisfactory distances and spacing; and for long-term or permanent loading, safe loads per connection are shown in figures 92 and 93 . The values may be increased 15 percent for loads applied for periods of not over 3 months or for snow loads, 50 percent for 0 wind or earthquake loads, or 100 percent for impact loads.


Figure 92. Safe loads for one $2 \nmid 2-$ inch ring and bolt in single shear.


Figure 99. Safe loads for one 4 -inch ring and bolt in single shear.

# CHAPTER 10 <br> MATERIALS OF CONSTRUCTION 

## Section I. WOOD

## 178. Board Measure

a. Lumber quantities are expressed in feet, board measure (ft. b.m.) or in board feet (bd. ft.), or in thousand board feet (M bd. ft.). One board foot (or ft. b.m.) is the amount of lumber in a rough-sawed board 1 foot long, 1 foot wide, and 1 ineh thick ( 144 eubic inehes) or the equivalent volume in any other shape. These original or "nominal" dimensions and volumes determine the number of board feet in a given quantity of dressed lumber, regardless of the faet that the proeess of surfaeing or other maehining has redueed the aetual dimensions and volume. Under American standards, for example, a dressed board designated as 1 inch by 12 inehes is in fact ${ }^{25 / 32}$ ineh by $11 \frac{1}{2}$ inches. This must be taken into aecount in computing the amount of lumber needed for a given job. Thus, one hundred 1 -inch by 12 -inch dressed boards 16 feet long eontain $\frac{100 \times 1 \times 12 \times 16}{12}=1,600$ board feet, but have an aetual area of only $\frac{100 \times 111 / 2 \times 16}{12}=1,533$ square feet; so that if 1,600 square feet of 1 -inch by 12 -inch material are desired, 1,670 board feet, plus allowance for wastage, must be ordered.
b. Table 185 gives the number of board feet in one pieee of lumber of the sizes given.

## 179. International Log Rule

A log rule, or seale, is marked at each ineh with the number of board feet which ean be sawed from logs if the log is measured inside the bark at the small end. Many such rules have been devised, recognized in the lumber industry, and used in various localities. The international $1 / 4$-inch log rule, whieh is based on $1 / 4$-inelı saw kerfs, has been adopted by statute in some states and may eventually beeome the universal standard. In applying the rule, no interpolation is made for diameters between ineh marks, but sealing praetiee in some localities permits using the next higher ineh for diameters with a fraction larger than $1 / 2$ ineh; for example, a $\log 23^{3 / 4}$ inehes in diameter is sealed as 24 inches. The seale is given in table 186.

Table 185. Board Feet

| Size of plece (iuches) | Length of piece (feet) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 10 | 12 | 14 | 10 | 18 | 20 | 22 | 24 |
| 2 by 4 | 6\%/3 | 8 | $91 / 3$ | 102/3 | 12 | $131 / 3$ | 142/3 | 16 |
| 2 by 6 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 2 by 8 | 131/3 | 16 | 182/3 | 211/3 | 24 | 262/3 | $291 / 3$ | 32 |
| 2 by 10 | 162/3 | 20 | 231/3 | $26 \frac{2}{3}$ | 30 | $331 / 3$ | $362 / 3$ | 40 |
| 2 by 12 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 2 by 14 | $231 / 3$ | 28 | $32{ }^{2 / 3}$ | $371 / 3$ | 42 | $46 \% 3$ | $511 / 3$ | 56 |
| 2 by 16 | $262 / 3$ | 32 | $371 / 3$ | 42\%/3 | 48 | $531 / 3$ | $582 / 3$ | 64 |
| 3 by 6 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
| 3 by 8 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 3 by 10 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 3 by 12 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 3 by 14 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 |
| 3 by 16 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 4 by 4 | $131 / 3$ | 16 | 182/3 | $211 / 3$ | 24 | $262 / 3$ | $291 / 3$ | 32 |
| 4 by 6 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 4 by 8 | 262/3 | 32 | $371 / 3$ | $422 / 3$ | 48 | $531 / 3$ | $581 / 3$ | 64 |
| 4 by 10 | $331 / 3$ | 40 | $462 / 3$ | $531 / 3$ | 60 | $66 \%$ | $731 / 3$ | 80 |
| 4 by 12 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 4 by 14 | 462/3 | 56 | 651/3 | 742/3 | 84 | 931/3 | 102\%/3 | 112 |
| 4 by 16 | $531 / 3$ | 64 | $74 \% / 3$ | 851/3 | 96 | 106 $2 / 3$ | 1171/3 | 128 |
| 6 by 6 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 6 by 8 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 6 by 10 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| 6 by 12 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 |
| 6 by 14 | 70 | 84 | 98 | 112 | 126 | 140 | 154 | 168 |
| 6 by 16 | 80 | 96 | 112 | 128 | 144 | 160 | 176 | 192 |
| 6 by 18 | 90 | 108 | 126 | 144 | 162 | 180 | 198 | 216 |
| 6 by 20 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 |
| 8 by 8 | $531 / 3$ | 64 | 74/3 | 851/3 | 96 | 106 ${ }^{2 / 3}$ | 1171/3 | 128 |
| 8 by 10 | $662 / 3$ | 80 | 931/3 | 1062/3 | 120 | 1331/3 | 146\%/3 | 160 |
| 8 by 12 | 80 | 96 | 112 | 128 | 144 | 160 | 176 | 192 |
| 8 by 14 | $13^{1 / 3}$ | 112 | 130\%/3 | 1491/3 | 168 | 186\%/3 | 2051/3 | 224 |
| 10 by 10 | $831 / 3$ | 100 | $116^{2 / 3}$ | 1331/3 | 150 | 1662/3 | 1831/3 | 200 |
| 10 by 12 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 |
| 10 by 14 | 1162/3 | 140 | 1631/3 | 186 ${ }^{2 / 3}$ | 210 | 2331/3 | 2562/3 | 280 |
| 10 by 16 | 1331/3 | 160 | 186\%/3 | 2131/3 | 240 | 2662/3 | 2931/3 | 320 |
| 12 by 12 | 120 | 144 | 168 | 192 | 216 | 240 | 264 | 288 |
| 12 by 14 | 140 | 168 | 196 | 224 | 252 | 280 | 308 | 336 |
| 12 by 16 | 160 | 192 | 224 | 256 | 288 | 320 | 352 | 384 |
| 14 by 14 | 1631/3 | 196 | 2282/3 | 261 $\frac{1}{3}$ | 294 | 326 $2 / 3$ | 3591/3 | 392 |
| 14 by 16 . | 186\%/3 | 224 | 2611/3 | 2982/3 | 336 | $3731 / 3$ | 4102/3 | 448 |

Table 186. Log Scale

| Dlameter (inches) | Length of $\log$ in feet (board measure) |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| 6.- | 10 | 10 | 15 | 15 | 20 | 25 | 25 |
| 7. | 10 | 15 | 25 | 30 | 30 | 35 | 40 |
| 8. | 15 | 20 | 25 | 35 | 40 | 45 | 50 |
| 9. | 20 | 30 | 35 | 45 | 50 | 60 | 70 |
| 10. | 30 | 35 | 45 | 55 | 65 | 75 | 85 |
| 11 | 35 | 45 | 55 | 70 | 80 | 95 | 105 |
| 12 | 45 | 55 | 70 | 85 | 95 | 110 | 125 |
| 13 | 55 | 70 | 85 | 100 | 115 | 135 | 150 |
| 14 | 65 | 80 | 100 | 115 | 135 | 155 | 175 |
| 15 | 75 | 95 | 115 | 135 | 160 | 180 | 205 |
| 16. | 85 | 110 | 130 | 155 | 180 | 205 | 235 |
| 17 | 95 | 125 | 150 | 180 | 205 | 235 | 265 |
| 18. | 110 | 140 | 170 | 200 | 230 | 265 | 300 |
| 19 | 125 | 155 | 190 | 225 | 260 | 300 | 335 |
| 20 | 135 | 175 | 210 | 250 | 290 | 330 | 370 |
| 21. | 155 | 195 | 235 | 280 | 320 | 365 | 410 |
| 22 | 170 | 215 | 260 | 305 | 355 | 405 | 455 |
| 23 | 185 | 235 | 285 | 335 | 390 | 445 | 495 |
| 24 | 205 | 255 | 310 | 370 | 425 | 485 | 545 |
| 25. | 220 | 280 | 340 | 400 | 460 | 525 | 590 |
| 26. | 240 | 305 | 370 | 435 | 500 | 570 | 640 |
| 27. | 260 | 330 | 400 | 470 | 540 | 615 | 690 |
| 28. | 280 | 355 | 430 | 510 | 585 | 665 | 745 |
| 29. | 305 | 385 | 465 | 545 | 630 | 715 | 800 |
| 30. | 325 | 410 | 495 | 585 | 675 | 765 | 860 |
| 31. | 350 | 440 | 530 | 625 | 720 | 820 | 915 |
| 32 | 375 | 470 | 570 | 670 | 770 | 875 | 980 |
| 33. | 400 | 500 | 605 | 715 | 820 | 930 | 1045 |
| 34 | 425 | 535 | 645 | 760 | 875 | 990 | 1110 |
| 35. | 450 | 565 | 685 | 805 | 925 | 1050 | 1175 |
| 36. | 475 | 600 | 725 | 855 | 980 | 1115 | 1245 |
| 37. | 505 | 635 | 770 | 905 | 1040 | 1175 | 1315 |
| 38. | 535 | 670 | 810 | 955 | 1095 | 1245 | 1390 |
| 39. | 565 | 710 | 855 | 1005 | 1155 | 1310 | 1465 |
| 40. | 595 | 750 | 900 | 1060 | 1220 | 1380 | 1540 |
| 41 | 625 | 785 | 950 | 1115 | 1280 | 1450 | 1620 |
| 42 | 655 | 825 | 995 | 1170 | 1345 | 1525 | 1705 |
| 43 | 690 | 870 | 1045 | 1230 | 1410 | 1600 | 1785 |
| 44 | 725 | 910 | 1095 | 1290 | 1480 | 1675 | 1870 |
| 45 | 755 | 955 | 1150 | 1350 | 1550 | 1755 | 1960 |
| 46 | 795 | 995 | 1200 | 1410 | 1620 | 1835 | 2050 |
| 47. | 830 | 1040 | 1255 | 1475 | 1695 | 1915 | 2140 |
| 48-- | 865 | 1090 | 1310 | 1540 | 1770 | 2000 | 2235 |
|  |  |  |  |  |  |  |  |

## Section II. STEEL PRODUCTS

## 180. Corrugated Sheet Metal

a. Black sheet iron with $21 / 2$-inch corrugations is stocked in oversca depots as a class IV item, in two sizes as follows:

| United States standard gage | Thichness <br> (inches) | Pounds per <br> squarefoot ${ }^{1}$ | Width <br> (inches) | Length <br> (feet) |
| :---: | ---: | ---: | ---: | ---: |
| 28 | 0.015 | 0.68 | 27 | 8 |
| 22 | -030 | 1.36 | 27 | 11 |
| 1 Based on sheets 27 inches wide, lapped 3 inches. |  |  |  |  |

1 Based on sheets 27 inches wide, lapped 3 inches.
b. Technical data on black and galvanized sheet metal with $2 \not 1 / 2$-inch corrugations are given in table 187.

## 181. Wire Rope.

a. General. Wire rope is manufactured from six types of metal and in many combinations of wire size, number of wires per strand, number of strands, and core types. Standard hoisting rope is made of 6 strands of 19 wires each, over a hemp core. It is flexible enough to operate over sheaves of practicable sizes. Using smaller wire sizes, ropes of 6 strands of 37 wires and of 8 strands of 19 wires are more flcxible and permit smaller sheave sizes. Using larger wires, ropes of 6 strands of 7 wires are suitable for standing rope service, such as guys and moorings. They require much larger sheaves if used over sheaves.
b. Sheave Sizes. Standard hoisting rope, 6 strands of 19 wires, requires a sheave diameter of 45 times the rope diameter to avoid excessive deterioration from bending stresses, and an absolute minimum sheave diameter of 30 times the rope diameter. Recommended

Table 187. Black and Galvanized Sheet Metal-21⁄2-inch Corrugations

| U.S. Standard gage | Thickness (mehes) | Pounds per square foot ${ }^{\text {a }}$ |  | Maximum span (feet) |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Galvanized | Black | Roofing | Siding |
| 28. | 0. 015 | 0. 85 | 0. 68 | $2^{\prime} 9^{\prime \prime}$ | $3^{\prime} 10^{\prime \prime}$ |
| 26. | . 018 | . 99 | . 82 | $2^{\prime} 9^{\prime \prime}$ | $3^{\prime} 10^{\prime \prime}$ |
| 24 | . 024 | 1. 26 | 1. 09 | ${ }^{-} 3^{\prime} 9^{\prime \prime}$ | $4^{\prime} 10^{\prime \prime}$ |
| 22. | . 030 | 1. 53 | 1. 36 | $4^{\prime} 9^{\prime \prime}$ | $5^{\prime} 10^{\prime \prime}$ |
| 20. | . 036 | 1. 81 | 1. 64 | $5^{\prime} 9^{\prime \prime}$ | $5^{\prime} 10^{\prime \prime}$ |
| 18. | . 048 | 2. 35 | 2. 18 | $5^{\prime} 9^{\prime \prime}$ | $5^{\prime} 10^{\prime \prime}$ |
| 16 | . 060 | 2. 90 | 2. 73 | $5^{\prime} 9^{\prime \prime}$ | $5^{\prime} 10^{\prime \prime}$ |
| 14. | . 075 | 3. 58 | 3. 41 | $5^{\prime} 9^{\prime \prime}$ | $5^{\prime} 10^{\prime \prime}$ |
| 12 | . 105 | 4. 94 | 4. 77 | $5^{\prime} 9^{\prime \prime}$ | $5^{\prime} 10^{\prime \prime}$ |

[^41]and minimum sheave diameters for standard and other wire ropes are given in table 188.

Table 188. Sheave Diameters for Wire Rope

| Type of wire rope (strands | Recommended sheave or drum diameter | Minimum sheave or drum diameter |
| :---: | :---: | :---: |
| 6 by 7 | $72 \times$ rope diameter | $42 \times$ rope diameter |
| 6 by 19 | $45 \times$ rope diameter | $30 \times$ rope diameter. |
| 6 by 37 | $27 \times$ rope diameter | $18 \times$ rope diameter. |
| 8 by 19 | $31 \times$ rope diameter.... | $21 \times$ rope diameter. |

c. Breaking Strength. While the breaking strength of wire rope varies slightly with the strand construction and number of strands, it depends primarily upon the type of metal used. The breaking strength of standard 6 by 19 hoisting rope, given in table 189 for each type of metal, is about 10 percent higher than that of 6 by 7 standing rope and slightly lower than that of some of the more flexible wire ropes.
d. Safety Factors. The minimum safety factors for new wire rope in various types of service are given in table 190. These factors are increased for high-speed operation, impact, inadequate sheave diameters, for old or worn rope, or if the results of a failure would be exceptionally serious.

## 182. Wire Rope Requirements for Engineer Equipment

Table 191 gives wire rope requirements for seleeted engineer equipment.

Table 189. Breaking Strength of Wire Rope


| Type of service | Minimum safety factor |
| :---: | :---: |
| Track cables | 3. 2 |
| Guys | 3. 5 |
| Cable tools operating at depths in fe |  |
| 0 to 500 | 8. 0 |
| 500 to 1000 | 7. 0 |
| 1000 to 2000 | 6. 0 |
| 2000 to 3000 | 5. 0 |
| 3000 and over | 4. 0 |
| Miscellaneous hoisting equipment | 5. 0 |
| Haulage ropes . | 6. 0 |
| Derricks | 6. 0 |
| Slings | 8. 0 |

## 183. Wire-Rope Accessories

a. Types. Clips (U-bolts and saddles) and thimbles are shown in figure 94 ; spliced loops and various types of soekcts in figure 95.
b. Efficiency. Based on careful makeup, eonneetion strengths are given in table 192 in percentages of the breaking strength of new wire rope. Basket soekcts should be made up with zinc at $830^{\circ} \mathrm{F}$., but the strength when made up with lead or babbitt metal is given for reference in ease such soekets are found in use. The figures given are the maximum allowable and can be counted on only under ideal conditions.

## 184. Chains and Hooks

a. Chains. For typical straight-link chain, the safe load in tons is approximately eight times the square of the diameter in inches of the rod used to make the ehain. If the type of metal used in the ehain is known, safe loads are given more aceurately by table 193.


Figure 94. Wire-rope clips and thimbles.


LOOP WITH THIMBLE


LINK AND THIMBLE


THIMBLE AND SHACKLE


HOOK AND THIMBLE

BRIDGE SOCKET


Figure 95. Wire-rope filtings.

| Item of equrment | Attachment and application | Length (feet) | Diameter (inches) |
| :---: | :---: | :---: | :---: |
| Crane, revolving, tractor mounted, 6,000-th eapacity at 12-ft. radius; FSN 3830-240-7647. | Frection_ | 25 | 1/2 |
|  | Boom suspension cable_ | 96 | 1/2 |
|  | Crane hoist eable_ | 3 times boom length plus 15 ft .- | 1/2 |
|  | Dragline hoist eable | Twice boom length plus 15 ft . | 5/8 |
|  | Dragline drag eable | Brom length plus 25 ft . | 5/8 |
|  | Dragline domp cable | 13.-..... | 5/8 |
|  | Clamshell hotding cable. | Twice boom length plus 15 ft .-- | 1/2 |
|  | Clamsholl closing cable | Twiec boom length plus 45 ft . | 1/2 |
|  | Tagline. | 45-..--- | 5/10 |
|  | Shovel hoist, cable | 90 | 5/8 |
|  | Shovel crowd cable. | (i0) | 5/8 |
|  | Dipper trip line. | 36 | 1/4 |
|  | Back loe hoist cable. | 65 | 1/2 |
|  | Back hoe clrag cable_ | 65 | 5/8 |
|  | Back hoe dipper cable. | 45 | 5/8 |
| Crane shovel, basie mit, erawler mounted, 10 tons, $30-\mathrm{ft}$. boom at $12-\mathrm{fi}$. rarlius; MIL-C-15467; FSN 3810-188-7060. | Clamshell holding line_ | 108 | 5/8 |
|  | Clamshell closing liuc. | 120 | 5/8 |
|  | Shovel hoisi, line. | 80 | 5/8 |
|  | Shovel trip line- | 42 | 5/16 |
|  | Shovel boom line. | 118. | 1/2 |
|  | Pull slovel hoist line. | 10.5 | 5/8 |
|  | Pull shovel pull-iu line. | 60. | $3 / 4$ |
|  | Pull shovel hait line. | 81 | 11/2 |
|  | Crane boomi line. | 326 | 1/2 |
|  | Dragline.-- | (i.) | $3 / 4$ |
|  | 2-part hoist line | 156 | 5/8 |

Crane shovel, crawler mounted, 40 ton, $50-\mathrm{ft}$. boom at 12 -ft. radius, 2 cu. yd.; MIL-C-15467; FSN 3810-230-3819.

Crane shovel power unit, revolving, truck mounted $121 / 2$ ton; MIL-C-10466; FSN 3810-264-4842.


Table 191. Wire Rope Requirements for Engineer Equipment-Continucd

| Item of equipment | Attachment and application | Length (feet) | Diameter (inches) |
| :---: | :---: | :---: | :---: |
|  | Closing: |  |  |
|  | $30-\mathrm{ft}$ boom | 90 | 1/2 |
|  | $40-\mathrm{ft}$ boom | 110. | 1/2 |
|  | Tagline. | 60 | 3/8 |
|  | Dragline: <br> Hoist. |  |  |
|  | $30-\mathrm{ft}$ boom | 85 | 1/2 |
|  | $35-\mathrm{ft}$ boom. | 95 | 1/2 |
|  | $40-\mathrm{ft}$ boom | 105 | 1/2 |
|  | Drag: |  |  |
|  | $30-\mathrm{ft}$ boom | 40 | 5/8 |
|  | $35-\mathrm{ft}$ boom | 45 | 5/8 |
|  | $40-\mathrm{ft}$ boom. | 50 | 5/8 |
|  | Dump | 20 | 5/8 |
| Ditching machine, crawler mounted, gas-engine driven; MIL-D-633; FSN 3805-221-1716. |  | 82 | 1/2 |
| Mixer, concrete, trailer mounted, gas-enginc driven, | Skip cable | 24 | 5/18 |
| ```6 cu. ft. capacity; JAN-M-686; FSN 3895-238- 5089.``` | Hoist cable. | 34 | 5/16 |
| Mixer, concrete, trailer mounted, $16 \mathrm{cu} . \mathrm{ft}$. capacity; | Skip cable | 24 | 5/18 |
| JAN-M-686; FSN 3895-238-5097. | Hoist cable | 34 | 5/11 |
| Paver, concrete, crawler mounted, gas-engine driven, | Bucket wire rope, short | $52^{\prime} 6^{\prime \prime}$ | $3 / 8$ |
| dual drum, 34 cu . ft. per batch capacity; MIL-M- | Bucket wire rope, long- | 84 | 3/8 |
| 3362; FSN 3895-239-8649. | Boom support cable | 130 | 5/8 |
|  | Skip hoist cable.---- | $56^{\prime} 6^{\prime \prime}$ | 3/4 |

Rooter, road, towed, cable operated; MII-R-587; FSN 3895-234-2542.

Scraper, earth moving, towed, 12 cu. yd., 4 wheeled, pneumatic tire; I MIL-S-3084; FSN 3805-1978582.

Tractor, full tracked, low speed, diesel driven, medium drawbar pull; MIL-T-12229.


Table 192. Wire-Rope Connections

| Connection | Description | Maximum percent of strength of new wire rope |
| :---: | :---: | :---: |
| Three clips | See figure 94 | 80. |
| Basket sockets. | Made with zinc at $830^{\circ} \mathrm{F}$ | 80. |
|  | Made with lead or babbitt metal. | 25 or more. |
| Thimble in spliced eye | Rope diameters - - 1/4' ${ }^{\prime \prime}$ | 100. |
| (fig. 95). | $3 / 8{ }^{\prime \prime}$ - $3 / 1^{\prime \prime}$ | 95. |
|  | $78^{\prime \prime}$ - $1^{\prime \prime}$ | 90. |
|  | $11 /{ }^{\prime \prime}$ - $11 / 2^{\prime \prime}$ | 80. |
|  | 15/8' $\mathbf{\prime}^{\prime \prime}$ 2' | 75. |
|  | 21/4' ${ }^{\prime \prime}$ and up. | 70. |

Table 193. Safe Loads on Chains

| Dia of metal (inches) | Approximate weight per 100 feet, pounds | Safe load in tons |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $W^{\text {r }}$ rought iron | Hygh-grade wrought-iron | Soft | Special steel |
| 3/8- | 160 | 1. 35 | 1. 49 | 1. 65 | 3. 20 |
| 7/16 | 210 | 1. 73 | 1. 90 | 2. 18 | 4. 15 |
| $1 / 2$ | 280 | 2. 25 | 2. 48 | 2. 63 | 5. 25 |
| 5/8 | 430 | 3. 47 | 3. 81 | 4. 23 | 7. 60 |
| $3 / 4$ | 630 | 5. 07 | 5. 58 | 6. 00 | 10. 50 |
| 7/8 | 840 | 7. 00 | 7. 70 | 8. 25 | 14. 33 |
| 1.--------------- | 1, 100 | 9. 30 | 10. 23 | 10. 60 | 18. 20 |

b. Hooks. The safe load in tons for a hook is approximately the square of the diameter in inches of the metal used to make the hook. Dimensions and safe loads for hooks are given more accurately in table 194.

Table 194. Safe Loads on Hooks

| Diameter of metal (inches) | Inside diameter of eye (inchrs) | Width of opening (inches) | Safe load (tons) ${ }^{\text {' }}$ |
| :---: | :---: | :---: | :---: |
| 5/8- | 3/4 | 1 | 0.5 |
| 11/10 | 7/8 | 11/16 | 0.6 |
| 3/4. | 1 | 118 | 0. 7 |
| 7/8- | 1/8 | 11/4 | 1. 2 |
| 1 -- | 11/4 | 13/8 | 1. 7 |
| 1/8- | 13/8 | $11 / 2$ | 2. 1 |
| 11/4- | 11/2 | $111 / 16$ | 2. 5 |
| 13/8 | 15/8 | $17 / 8$ | 3. 0 |
| $11 / 2$ | 13/4 | 21/10 | 4. 0 |
| 15/8- | 2 | 21/4 | 4. 7 |
| 17/8- | 21/8 | 21/2 | 5. 5 |
| 21/4 | 23/4 | 3 | 6. 8 |
| 25/8-- | 31/8 | $33 / 8$ | 8. 5 |
| 3--- | 31/2 | 4 | 12.0 |

## Section III. CONCRETE AND CONCRETE MATERIALS

## 185. Concrete Materials

a. Cement. In the United Statcs, portland cement is shipped cither in bulk or in paper or cloth bags holding 94 pounds, 1 cubic foot, loose measure. Europcan portland cement is very similar to that made in the United States, but it is shipped in bags of 110 pounds and in some cases in wooden barrels.
b. Fine Aggregate. Fine aggrcgatc consists of well-graded particles $1 / 4$ inch and smaller. Clay, silt, and dust may not excced 3 percent by weight of the fine aggregatc.
c. Coarse Aggregate. The commonly uscd coarsc aggregates are gravel and crushed rock. They should consist of clean, hard, strong, and curable particles.
d. Reinforcing Rods. (See paragraph 165.)
e. Average Weights of Materials Used in Concrete Construction. Concrete material weights are shown bclow.

| Item | Average weight |
| :---: | :---: |
| Aggregate, coarse | 2,500 pounds per cubic yard. |
| Aggregate, fine | 2,800 pounds per cubic yard. |
| Aggregate, combined coar | 2,600 pounds per cubic yard. |
| Concrete | 4,000 pounds per cubic yard. |
| Form lumber | 3,000 pounds per thousand board measure. |
| Reinforcing steel, bundled | 380 pounds per cubic foot. |
| Reinforcing steel | 5 to 30 pounds per cubic yard of concrete. |

## 186. Concrete Proportioning

a. Water-Cement Ratio. See table 196.
b. Slump. Table 195 gives a range of suggested valucs of slump for various types of structure; in making a selection in a particular case, however, consideration must be given to structural details.
c. Coarse Aggregate. Coarse aggregate should be graded up to the maximum size that the nature of the job permits. This depends on the size and shape of the concrete members and on the amount and

Table 195. Slump Values

| Type of construction | Slump in inches |  |
| :---: | :---: | :---: |
|  | Maximum | Minimum |
| Reinforcing foundation walls and footing | 5 | 2 |
| Plain footings, caissons, and substructure | 4 | 1 |
| Slabs, beains, and reinforced walls | 6 | 3 |
| Building columns. | 6 | 3 |
| Pavements. | 3 | 2 |
| Heavy mass construction | 3 | 1 |

[^42]distribution of the reinforcing steel. In general it should not exceed either $1 / 5$ the least dimension of the member of $3 / 4$ the minimum clear space between reinforcing bars (or between a bar and the nearest form). For a pavement slab it should not exceed $1 / 3$ the thickness of the slab. A common range of maximum sizes is from $1 / 4$ inch to 2 inches.
d. Proportions of Mix. Table 196 gives suggested proportions for various combinations of water-cement ratio and the maximum size of aggregate.
e. Adjustment for Moisture. The figures in table 196 are for saturated surface dry aggregates. They will require adjustment if the aggregate, especially the dry aggregate, contains a considerable amount of moisture.

## 187. Forms

a. Wall Forms. Wall forms (fig. 99) are normally constructed of wood sheathing 1 to 2 inches thick carried on studs and wales 2 by 4 to 3 by 8 inches. The required stud and wale spacings depend on the concrete temperature, the rate of placing concrete, and the sheathing thickness. They are determined as follows:
(1) The maximum pressure against wall forms depends upon the concrete temperature and the rate of placing, the latter in feet of height per hour. The pressure resulting from various combinations of these are shown in figure 96 :
(2) With surfaced sheathing of nominal thickness of 1 to 2 inches, the maximum stud spacing for various concrete pressures is shown in figure 97.
(3) Based on various combinations of sheathing and stud sizes, the maximum wale spacing is similarly shown in figure 98 .
(4) Example.
(a) Problem. One hundred linear feet of concrete wall 1 foot thick is to be placed at a rate of 10 cubic yards per hour at a temperature of $70^{\circ} \mathrm{F}$. What spacings are required for 2 - by 4 -inch studs and wales, using 1 -inch sheathing?
(b) Solution.
$\frac{\text { Cubic yards of concrete }}{\text { per foot of wall height }}=\frac{100 \times 1}{27}=3.7$
Feet of wall height placed per hour $=\frac{10}{3.7}=2.7$
Maximum concrete pressure ((1) above) $=400$ pounds per square foot
Maximum stud spacing ((2) above) $=19$ inches
Maximum wale spacing ((3) above) $=31$ inches.

Figure 96. Maximum concrete pressures against wall forms.

| Maximum size ef aggregate (inches) | Water (gallons per sack of cement) | Water (gullons per cubic yard of concrete) | Cement (sacks per cuble yard of concrete) | Fine agyregate (percent of total aggregate) | Fine aggregate (pounds per sack of eenent) | Coarse aggregate (pounds per sack of cement) | Fine aguregate (pounds per cubic yard of concrete) | Coarse aggregate (pounds per cuble yard of concrete) | Yleld (cuble feet of concrete per sack of eement) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $3 / 4$ | 5 | 38 | 7. 6 | 43 | 170 | 230 | 1,290 | 1,750 | 3. 56 |
| 1 | 5 | 37 | 7. 4 | 38 | 160 | 255 | 1, 185 | 1,890 | 3. 65 |
| 11/2 | 5 | 35 | 7. 0 | 34 | 150 | 300 | 1, 050 | 2, 100 | 3. 86 |
| 2 | 5 | 33 | 6. 6 | 31 | 150 | 335 | 990 | 2, 210 | 4. 09 |
| 3/4 | 51/2 | 38 | 6. 9 | 44 | 195 | 250 | 1,345 | 1, 725 | 3. 91 |
| 1 | 51/2 | 37 | 6. 7 | 39 | 180 | 285 | 1,205 | 1, 910 | 4. 03 |
| 1/22 | 51/2 | 35 | 6. 4 | 35 | 175 | 320 | 1, 120 | 2, 050 | 4. 22 |
| 2 | 51/2 | 33 | 6. 0 | 32 | 175 | 370 | 1, 050 | 2, 220 | 4. 50 |
|  | 6 | 38 | 6. 3 | 45 | 225 | 275 | 1, 420 | 1,730 | 4. 29 |
| 1 | 6 | 37 | 6.2 | 40 | 205 | 305 | 1,270 | 1, 890 | 4. 36 |
| 11/2 | 6 | 35 | 5. 8 | 36 | 200 | 355 | 1, 160 | 2, 060 | 4. 66 |
| 2 | 6 | 33 | 5. 5 | 33 | 200 | 400 | 1, 100 | 2, 200 | 4. 91 |
| 3/4 | 6122 | 38 | 5. 9 | 46 | 245 | 288 | 1, 445 | 1, 700 | 4. 58 |
| 1 | 6/2 | 37 | 5. 7 | 41 | 230 | 330 | 1, 310 | 1,880 | 4. 74 |
| 11/2 | 6 $1 / 2$ | 35 | 5. 4 | 37 | 225 | 380 | 1, 215 | 2, 050 | 5. 00 |
| 2 | 61/2 | 33 | 5. 1 | 34 | 225 | 430 | 1, 150 | 2,195 | 5. 30 |
| 3/4 | 7 | 38 | 5. 4 | 47 | 280 | 315 | 1, 510 | 1,700 | 5.00 |
| 1 | 7 | 37 | 5. 3 | 42 | 255 | 355 | 1,350 | 1, 880 | 5. 10 |
| 1122 | 7 | 35 | 5. 0 | 38 | 250 | 410 | 1, 250 | 2, 050 | 5. 40 |
| 2 | 7 | 33 | 4. 7 | 35 | 250 | 465 | 1,175 | 2, 185 | 5. 75 |


|  | 71/21 | 38 | 5. 1 | 48 | 300 | 330 | 1,530 | 1,680 | 5. 30 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | 71/2 | 37 | 4. 9 | 43 | 285 | 380 | 1, 400 | 1, 860 | 5. 51 |
| 1/2/2 | 71/2 | 35 | 4. 7 | 39 | 275 | 430 | 1, 290 | 2, 020 | 5. 75 |
| 2 | 71/2 | 33 | 4. 4 | 36 | 275 | 495 | 1,210 | 2, 180 | 6. 14 |
| $3 / 4$ | 8 | 38 | 4.8 | 49 | 330 | 345 | 1,585 | 1,655 | 5. 63 |
| 1 | 8 | 37 | 4. 6 | 44 | 315 | 400 | 1,450 | 1, 840 | 5. 87 |
| 11/2 | 8 | 35 | 4. 4 | 40 | 305 | 455 | 1,340 | 2, 000 | 6. 14 |
| 2 | 8 | 33 | 4. 1 | 37 | 310 | 525 | 1,270 | 2, 150 | 6. 59 |
| 3/4 | 5 | 38 | 7.6 | 45 | 180 | 220 | 1,370 | 1,670 | 3. 56 |
| 1 | 5 | 37 | 7. 4 | 40 | 165 | 250 | 1,220 | 1,850 | 3. 65 |
| 1120 | 5 | 35 | 7. 0 | 36 | 160 | 290 | 1,120 | 2, 030 | 3. 86 |
| 2 | 5 | 33 | 6.6 | 33 | 160 | 325 | 1,055 | 2, 140 | 4. 09 |
|  | $5{ }^{2}$ | 38 | 6.9 | 46 | 205 | 240 | 1, 415 | 1,655 | 3. 91 |
| 1 | 51/2 | 37 | 6.7 | 41 | 190 | 275 | 1,270 | 1,840 | 4. 03 |
| $11 / 2$ | 51/2 | 35 | 6. 4 | 37 | 185 | 315 | 1,185 | 2, 015 | 4. 22 |
| 2 | 51/2 | 33 | 6. 0 | 34 | 185 | 360 | 1,110 | 2, 160 | 4. 50 |
|  | 6 | 38 | 6.3 | 47 | 235 | 265 | 1,480 | 1,670 | 4. 29 |
| 1 | 6 | 37 | 6. 2 | 42 | 215 | 295 | 1,335 | 1, 830 | 4. 36 |
| 11/2 | 6 | 35 | 5. 8 | 38 | 210 | 345 | 1,220 | 2, 000 | 4. 66 |
| 2 | 6 | 33 | 5. 5 | 35 | 210 | 390 | 1,155 | 2,145 | 4.91 |
| $3 / 4$ | $61 / 2$ | 38 | 5. 9 | 48 | 255 | 280 | 1,505 | 1,650 | 4. 58 |
| 1 | 61/2 | 37 | 5. 7 | 43 | 240 | 320 | 1,370 | 1,825 | 4. 74 |
| 11/2 | 61/2 | 35 | 5. 4 | 39 | 235 | 370 | 1,270 | 2, 000 | 5. 00 |
| 2 | 61/2 | 33 | 5.1 | 36 | 235 | 415 | 1,200 | 2, 120 | 5. 30 |


| With fine sand-fineness modulus $2.20-260$ |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Maximum size of aggregate (inches) | Water (gat- <br> lons per sack of cement) | Water (gallons per eulie yard of conerete) | Cement (sacks per cubie yard of concrete) | Fine aggregate (percent of total agbregate) | Flne aggregate (pounds per sack of cement) | Coarse aggregate (pounds per sack of centent) | Fine aggregate (pounds per cubic yard of concrete) | Coarse aggregate (pounds per cuble yard of concrete) | Yield (cubic feet of concrete jer suck of cement) |
|  | 7 | 38 | 5. 4 | 49 | 290 | 305 | 1,565 | 1,650 | 5. 00 |
| 1 | 7 | 37 | 5. 3 | 41 | 270 | 340 | 1, 430. | 1, ${ }^{1} 800$ | 5. 5.10 |
| $11 / 2$ | 7 | 35 | 5. 0 | 40 | 265 | 395 | 1, 325 | 1,975 | 5. 40 |
| 2 | 7 | 33 | 4. 7 | 37 | 265 | 450 | 1,245 | -2,120 | 5. 75 |
| $3 / 4$ | $71 / 2$ | 38 | 5.1 | 50 | 315 | 315 | 1, 605 | 1, 605 | 5. 30 |
| 1 | 71/2 | 37 | 4. 9 | 45 | 300 | 365 | 1,470 | 1, 790 | 5. 51 |
| $11 / 2$ | 71/2 | 35 | 4. 7 | 41 | 290 | 415 | 1,365 | 1,.950 | 5. 75 |
| 2 | 71/2 | 33 | 4. 4 | 38 | 290 | 480 | 1, 275 | 2,110 | 6. 14 |
| $1^{3 / 4}$ | 8 | 38 | 4. 8 | 51 | 345 | 330 | 1, 660 | 1,585 ${ }^{\circ}$ | 5. 63 |
| 1 | 8 | 37 | 4. 6 | 46 | 330 | 385 | 1,520 | 1,770 | 5. 87 |
| 11/2 | 8 | 35 | 4. 4 | 42 | 320 | 440 | $\cdot 1,410$ | 1,935 | 6. 14 |
| 2 | 8 | 33 | 4. 1 | 39 | 325 | 510 | 1,330 | 2,090 | 6. 59 |
| $1^{3 / 4}$ |  | 38 | 7. 6 |  |  |  |  |  |  |
| 1 | 5 | 37 | 7. 4 | 42 | 175 | 240 | 1, 295 | 1,595 1,775 | 3. 56 3. 65 |
| $11 / 2$ | 5 | 35 | 7. 0 | 38 | 170 | 280 | 1, 190 | 1,960 | 3. 65 3. 86 |
| 2 | 5 | 33 | 6.6 | 35 | 170 | 315 | 1,120 | 2,080 | 4. 09 |
| 3/4 | 51/2 | 38 | 6. 9 | 48 | 215 | 230 | 1, 480 |  |  |
| 1 | 51/2 | 37 | 6. 7 | 43 | 200 | 265 | 1,340 | 1, 775 | 4. 03 |
| 11/2 | 51/2 | 35 | 6. 4 | 39 | 195 | 305 | 1,250 | 1,950 | 4. 22 |
| 2 | 51/2 | 33 | 6. 0 | 36 | 195 | 350 | 1, 170 | 2, 100 | 4. 50 |




MAX LAUM CONCRHTE: FRESSURE $100 \mathrm{LBS} / \mathrm{FF}^{2}$ ?
Figure 97. Maximum stud spacing for wall forms.
b. Slab Forms. Slab forms are designed to carry the full load of freshly placed concrete.
c. Column Forms. Column forms are built as shown in figure 100, with yokes of 2-by 4 -inch limber spaced as shown in figure 101.
d. Anchor Bolts. For buildings and in other light construction, anchor bolts are installed as shown in figure 102, with the upper


Figure 95. Maximum wale spacing for wall forms.


Figure 99. Wall forms and braces.
part of each enclosed in a 6-inch length of pipe or sheet-metal tubing to permit a slight lateral adjustment in bolt positioning.
e. Steel Pavement Forms.
(1) Standard steel pavement forms are rapidly and accurately set and should be used when obtainable. They are made


Figure 100. Column forms.

LARGEST DIMENSION OF COLUMN IN INCHES a/

a/ EXAMPLE: TO FIND THE YOKE SPACING FOR A 12-FOOT COLUMN THE LARGEST DIMENSION OF WHICH IS 16 INCHES, READ UP FROM 12 -FOOT HEIGHT IN THE COLUMN HEADED 16 INCHES. YOKES ARE SPACED AT 21 INCHES, 29 INCHES, 30 INCHES AND 31 INCHES.

Figure 101. Yoke spacing for various sizes and heights of columns.
of $3 / 16$-inch stcel plate in sections 10 fect long. Forms for slab thicknesses of $6,7,8,9,10$, and 12 inches can normally be obtained in the zone of intcrior. The usual basc-plate width is 8 inches. The base-plate width should be cqual to or greater than the facc depth. Locking plates rigidly join the ends of the sections. Three stecl stakes, 1 inch in diametcr, per 10 -foot scction of form are required.
(2) After the stakes are driven, the form is set true to line and grade and clamped to the stakes by special splines and wedges. Forms are set on the subgrade ahead of the paver


Figure 102. Installation of anchor bolts.
and must be left in place for at least 24 hours after the concrete is placed.
(3) The forms must be oiled just before the concrete is placed. After a form is completely oiled, the top side or traction edge must be wiped free of oil.
(4) The forms are removed as soon as practicable, cleaned, oiled, and stacked in neat piles ready for reuse.

## Section IV. BITUMINOUS CONSTRUCTION MATERIALS

## 188. Bituminous Materials

Table 197 lists the principal asphalt and tar products used in paving, with their source, form in which marketed, grade designation, temperature of application, and other data.

## 189. Bituminous Surface Treatment

Table 198 gives the gradation requirements for aggregates. Tables 199 and 200 give the quantities of aggregate and bitumen for singlesurface and double-surface treatments, respectively.

Table 197. Bituminous Materials


| Asphaltic eernents (AC) or paving asphalts. | -----do---------------- | Semiliquids or solids -- | $\begin{aligned} & 40-50^{1} \\ & 50-60^{1} \\ & 60-70^{1} \\ & 70-80^{1} \\ & 85-100^{1} \\ & 100-120^{1} \\ & 120-150^{1} \\ & 150-200^{1} \\ & 200-300^{1} \end{aligned}$ | $275^{\circ}-350^{\circ}$ $275^{\circ}-350^{\circ}$ | $275^{\circ}-325^{\circ}$ $200^{\circ}-275^{\circ}$ | Penctration 40 to 100 used for eraek and joint fillers. Penetrations 70 to 300 used for plant mixes, penetration macadam, and surface treatment. Comparable grades, Federal Specification SS-A-706b: 50-60 penetration, AP-5; 85-100 penetration, AP-3; 100-120 penetration, A P-2; 120-150 penetration, AP-1. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Powdered asphalt $(\mathrm{PA}) .$ | ---d0---------------- | Thard and solld asphaits ground to powder. |  |  |  | Used with SC oils to produce extra tough road surface |
|  |  |  | Rapid, | dium, and | ow setting |  |
| Asphalt emulsions (AE). | Asphalt coments in water with an emulsifying agent. | Liquids.------------- | RS-1 <br> MS-1 <br> MS-2 <br> MS-3 <br> SS-1 <br> SS-2 | $50^{\circ}-140^{\circ}$ | $50^{\circ}-140^{\circ}$ | Freezing destroys emulsion, penctration, and surface treatments. Road and plant mixes with coarse aggregate. Road and plant mixes with fine aggregate. Grades and typical uses of asphalt emulsions under Federal Specification SS-A-674a are as follows: Grade I, Surface treatments, seal coats. Grade II, Opengraded coarse aggregate mixed-in-place. Grade III, Summer use in bituminous concrete mixtures for repair work. Grade IV, winter use in bituminous conerete mixtures for repair work. Grade V, Penetration macadam and surface treatments. Grade VI, Fine aggregate mixes in whieh a substantial quantlty of aggregate passes $3 / 8$-ineh sieve and a portion may pass a No. 200 sieve. |

${ }^{1}$ Penetrations of $100,120,150,200$, and 300 show inereasing softness of fluldlty. Penetrations of $85,70,60,50,40$, and so on, showing inereasing hardness or solidity road oil SC5 (with high viseosity) and the softest paving asplialts both have penetrations of about 200.

Table 197. Bituminous Materials-Continued


Table 198. Gradation Requirements for Aggregates for Bituminous Surface Treatments

| Sieve designation | Percent passing each sieve (square opening) by weight |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Gradation designations |  |  |  |  |  |  |  |  |
|  | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No. 61 | No. 71 | No. $8^{1}$ | No. 91 |
| 11/2-inch. | 100 |  |  |  |  |  |  |  |  |
| 1-inch_ | 90-100 | 100 | 100 |  |  |  |  |  |  |
| 3/4-inch | 40-75 | 90-100 | 90-100 | 100 | 100 |  |  |  | -- |
| 1/2-inch. | 15-35 | 20-55 |  | 90-100 | 90-100 | 100 |  |  |  |
| 3/8-inch | 0-15 | 0-15 | 20-55 | 40-70 | 40-75 | 85-100 | 100 |  | 100 |
| No. 4 | 0-5 | 0-5 | 0-10 | 0-15 | 5-25 | 10-30 | 85-100 | 100 | 95-100 |
| No. 8. |  |  | 0-5 | 0-5 | 0-5 | 0-10 | 10-40 | 50-100 |  |
| No. 10 |  |  |  |  |  |  |  | 0-5 |  |
| No. 16 |  |  |  |  |  |  | 0-10 |  | 45-80 |
| No. 50. |  |  |  |  |  |  |  |  | 5-30 |
| No. 100. |  |  |  |  |  |  |  |  | 0-8 |
|  |  |  |  |  |  |  |  |  |  |

${ }^{1}$ Clean sand may be used instead of erushed aggregates.
Table 199. Quantities of Aggregate and Bitumen for Single Surface Treatments

| Material | Unit of measurement | No. 2 | Gradation designations |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | No. 3 | No. 4 | No. 5 | No. 6 | No. 8 | No. 9 |
| Aggregate | Pounds per square yard.- | 35-45 | 35-45 | 25-35 | 25-35 | 15-25 | 10-20 | 10-15 |
| Bitumen.- | Gallons per square yard - - | 0. 35-0. 45 | 0.35-0. 45 | 0. 25-0. 35 | 0. 25-0.35 | 0.15-0.25 | 0. 10-0. 20 | $0.10-0.15$ |

Table 200. Quantities of Aggregate and Bitumen for Double Surface Treatments

| Gradation designations | $\begin{aligned} & \text { Biturnen (gallons } \\ & \text { per square yard), } \\ & \text { first appli- } \\ & \text { cation } \end{aligned}$ | Aggregate (pounds per square $\mathbf{7 a r d ) , ~}$ frst spreading | Bitumen (gallons per square yard), first spreading | Aggregate (pounds per square yard). second spreading |
| :---: | :---: | :---: | :---: | :---: |
| No. 1 | 0.45-0.55 | 45-55 |  |  |
| No. 4 |  |  | 0. 2-0. 3 | 15-25 |
| No. 2 | 0. $40-0.50$ | 40-50 |  |  |
| No. 6 |  |  | 0. 2-0. 3 | 15-25 |
| No. 4 | 0.35-0. 45 | 35-45 |  |  |
| No. 7 |  |  | 0. 2-0. 3 | 15-25 |

## 190. Gradation Control and Bituminous Content

Table 201 gives recommended limits for gradation control, and suggested bituminous content for each gradation, for asphaltic surface courses. Tables 202, 203, and 204 give similar data for asphaltic binder courses, asphaltic base courses, and tar mixes.

## Section V. SOILS

## 191. General

For the control of soils in military construction, see TM 5-541. For data on soil classification and classification tests, the properties and engineering characteristics of soils, and soil surveys, see FM 5-250.

## 192. Soil Classification

Figure 103 gives the Unified Soil Classification system.

## 193. Identification of Soils

Figure 104 gives a summary of identification procedure, using laboratory test results.

## 194. Pertinent Characteristics of Soils

Figure 105 summarizes the characteristics of soils which are pertinent to road and airfield construction. Figure 106 gives similar data pertaining to embankment and foundation construction.

## Section VI. MISCELLANEOUS BUILDING MATERIALS AND HARDWARE

## 195. Wallboard, Insulation: Substitutes

Nomenclature, sizes, types and logistical data are given in table 205.


Figure 103. Unified Soil Classification system

Table 201. Recommended Limits for Gradation Control and Suggested Bitumen Content for Each Gradation, Asphaltic Surface Courses

| Maximum particle size (inches) | $\begin{aligned} & \text { Gradation } \\ & \text { No. } \end{aligned}$ | Rccommendedbitumen | Percent passing each sieve, by weight |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Sieve designation |  |  |  |  |  |  |  |  |  |  |
|  |  |  | $14 / 2 \mathrm{in}$. | 1 in . | 34 in . | 312 in . | 36 | No. 4 | No. 10 | No. 20 | No. 40 | No. 80 | No. 200 |
| 11/2------ | 1 | 4. 5-6.0 | 100 | 84-100 |  | 66-75 |  | 42-54 | 31-43 |  | 16-25 | 10-17 | 4. $0-7.5$ |
|  | 2 | 5. $0-6.5$ | 100 | 87-100 |  | 70-79 |  | 48-60 | 37-49 |  | 20-29 | 12-19 | 4. $5-7.5$ |
|  | 3 | 5. 5-7.0 | 100 | 90-100 |  | 75-84 |  | 54-66 | 43-55 |  | 25-34 | 15-22 | 5. $0-8.0$ |
| 1.-.-.-.-- | 1 | 5. $0-6.0$ |  | 100 | 85-100 | 72-87 | --- | 45-60 | 32-47 |  | 16-26 | 10-18 | 4. $0-8.0$ |
|  | 2 | 5. $0-6.5$ |  | 100 | 87-100 | 76-89 | ------- | 52-67 | 39-54 |  | 21-32 | 13-21 | 4. $5-8.5$ |
|  | 3 | 5. 5-7.0 |  | 100 | 90-100 | 82-93 |  | 60-75 | 47-62 |  | 26-37 | 16-24 | 5. 0-9. 0 |
|  | ${ }^{1} \mathrm{HP}$ | 5.0-6.5 |  | 100 | 89-100 | 78-90 | 69-83 | 55-70 | 42-56 | 30-43 | 22-33 | 14-22 | 3. $0-6.0$ |
| 3/4-------- | 1 | 5. 0-6.0 |  |  | 100 | 86-100 |  | 55-67 | 40-54 |  | 22-31 | 12-20 | 4. $0-8.0$ |
|  | 2 | 5.5-6.5 |  |  | 100 | 89-100 |  | 61-74 | 46-60 |  | 26-35 | .15-23 | 4. $5-8.5$ |
|  | 3 | 6.0-7.5 |  |  | 100 | 91-100 |  | 67-80 | 54-66 |  | 31-40 | 19-26 | 5. $0-9.0$ |
|  | 1 HP | 5. 5-6.5 |  |  | 100 | 86-100 | 78-90 | 60-73 | 43-57 | 29-43 | 19-33 | 10-20 | 3.0-6.0 |
| 1/2------- | 1 | 5. $0-6.5$ |  |  |  | 100 | 84-100 | 60-73 | 43-57 |  | 23-33 | 13-20 | 4. $0-8.0$ |
|  | 2 | 6. $0-7.5$ |  |  |  | 100 | 86-100 | 66-79 | 50-64 |  | 27-37 | 16-23 | 4. $5-8.5$ |
|  | 3 | 6.0-8.0 |  |  |  | 100 | 80-100 | 73-85 | 57-70 |  | 31-42 | 19-26 | 5. $0-9.0$ |
| 3/8-------- | 1 | 6. $0-9.0$ |  |  |  |  | 100 | 78-100 | 56-76 |  | 26-44 | 14-28 | 6. $0-10.0$ |
|  | 2 | 7. 0-10.0 |  |  |  |  | 100 | 80-100 | 60-80 |  | 29-47 | 16-30 | 7. 0-11. 0 |
|  | 3 | 8. $0-11.0$ |  |  |  |  | 100 | 82-100 | 64-84 |  | 32-50 | 18-32 | 8. $0-12.0$ |

[^43]Table 202. Recommended Limits for Gradation Control and Suggested Bitüticn Content for Each Gradation, Asphaltic Binder Courses

| Maximum particle size (inches) | $\begin{gathered} \text { Gradation } \\ \text { No. } \end{gathered}$ | Recommendedpercentbitumen | Percent passing each sieve, by weight |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Sieve designation |  |  |  |  |  |  |  |  |  |  |
|  |  |  | 2 in . | 1 $1 / 2 \mathrm{in}$. | 1 in. | 34 in . | 36 in . | 38 in . | No. 4 | No. 16 | No. 40 | No. 80 | No. 200 |
| 2.------- | 123 | 3. 5-5. 0 | 100 | 86-100 | 70-84 |  | 52-67 |  | 32-47 | 20-35 | 10-20 | 6-14 | 3-7 |
|  |  | 3. 5-5. 0 | 100 | 88-100 | 72-86 |  | 54-69 |  | 34-49 | 22-37 | 11-21 | 6-14 | 3-7 |
|  |  | 3. 5-5.0 | 100 | 90-100 | 74-88 |  | 57-72 |  | 37-52 | 25-40 | 12-22 | 7-15 | 3-7 |
| 1 $112-\ldots-{ }^{\text {- }}$ | 1 | 4. 0-6. 0 |  | 100 | 78-100 |  | .56-73 | --- | 35-51 | 23-38 | 11-21 | 6-14 | 3-7 |
|  | 2 | 4. 0-6. 0 | - ---- | 100 | 81-100 |  | 59-77 | ------ | 39-55 | 27-42 | 13-23 | 7-15 | 3-7 |
|  | 3 | 4. 0-6. 0 |  | 100 | 84-100 |  | 63-80 |  | 42-58 | 31-46 | 15-25 | 8-16 | 3-7 |
| 1.------- | 1 | 4. 0-6. 0 |  |  | 100 | 76-100 | 64-82 | ------- | 38-54 | 25-41 | 12-23 | 7-16 | 4-8 |
|  | 2 | 4. 0-6. 0 |  | ------ | 100 | 80-100 | 67-85 | ------- | 43-59 | 29-45 | 14-25 | 8-17 | 4-8 |
|  | 3 | 4. 0-6. 0 |  |  | 100 | 85-100 | 71-89 |  | 48-64 | 34-50 | 17-28 | 10-18 | 4-8 |
| 3/4------- | 1 | 4. 5-7. 0 |  |  |  | 100 | 74-100 | 60-80 | 42-60 | 28-46 | 14-26 | 8-18 | 4-8 |
|  | 2 | 4. 5-7. 0 |  |  | ---- | 100 | 80-100 | 64-84 | 47-65 | $33-51$ | 16-28 | 9-19 | 4-8 |
|  | 3 | 4. 5-7. 0 |  |  |  | 100 | 82-100 | 68-88 | 52-70 | 36-54 | 18-30 | 10-20 | 4-8 |
| 1/2------- | 123 | 4. 5-7. 0 |  |  |  |  | 100 | 74-100 | 50-71 | 32-53 | 16-29 | 10-20 | 4-9 |
|  |  | 4. 5-7. 0 |  |  |  |  | 100 | 78-100 | 54-75 | 36-57 | 18-31 | 11-21 | 4-9 |
|  |  | 4. 5-7. 0 |  |  |  |  | 100 | 82-100 | 59-80 | 41-62 | 21-34 | 12-22 | 4-9 |

Table 209. Recommended Limits for Gradation Control and Suggested Bitumen Content for Each Gradation, Asphallic Base Courses

| $\begin{aligned} & \text { Maximum } \\ & \text { partiole } \\ & \text { size (inches) } \end{aligned}$ | Recommendedpercentbitumen | Percent passing each sieve, by weight |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Sieve designation |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 21/2 in. | 2 in. | 1/82 in. | 1 in . | 34 in . | 1/2in. | 38 in . | No. 4 | No. 10 | No. 40 | No. 80 | No. 200 |
| 21/2- | 4. 0-6. 5 | 100 | 90-100 | 80-94 |  | 56-76 |  |  | 30-50 | 20-37 | 10-24 | 6-18 | 0-5 |
| 2 | 4. 0-6. 5 |  | 100 | 88-100 |  | 62-82 |  |  | 33-53 | 23-40 | 12-26 | 6-18 | 0-5 |
| $11 / 2$ | 4. 0-7.0 |  |  | 100 | -82-100 | 70-89 | 60-80 |  | 37-57 | 25-43 | 14-28 | 8-20 | $0-8$ |

Table 204. Recommended Limits for Gradation Control and Suggested Bilumen Content for Each Gradation, Tar Mixes.


[^44]

Table 205. Logistical Data, Wallboard and Other Building Materials

|  | Sizes |  |  | UnIt measure | Unitspercontainer | Type of container | One filled container |  | Common names |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Thick- | Width | Length |  |  |  | Weight (pounds) | Cublc feet |  |
| Board, masonite, tempered | $\left\{\begin{array}{l}1 / 4^{\prime \prime} \\ 1 / 4^{\prime \prime}\end{array}\right.$ | $\begin{aligned} & 48^{\prime \prime} \\ & 48^{\prime \prime} \end{aligned}$ | $\begin{gathered} 96^{\prime \prime} \\ 144^{\prime \prime} \end{gathered}$ | Sheet <br> Sheet | $\begin{array}{r} 50 \\ 5 \end{array}$ | Box- <br> Case. | $\begin{array}{r} 3,520 \\ 450 \end{array}$ | $\begin{array}{r} 116.28 \\ 13.62 \end{array}$ | Hardboard. <br> Tempered masonite. |
| Cement, bituminous plastic, asphaltic base. |  |  |  | Pound - . - - <br> Pound .-. . | $\begin{array}{r} 1 \\ 50 \end{array}$ | Can <br> Can | $\begin{array}{r} 1 \\ 53 \end{array}$ | $\begin{aligned} & 0.23 \\ & \text { 1. } 08 \end{aligned}$ | Roof eement. |
| Felt, roofing, asphalt saturated, 15 lb, Type I. | ----- | $36^{\prime \prime}$ | 144' ${ }^{\prime \prime}$ | Roll .-. . . - | 3 | Crate - | 217 | 8. 06 | Tarpaper. Roofing felt. |
| Fiber board, insulating, roof board, Class C. | $\left\{\begin{array}{l}1 / 2^{\prime \prime} \\ 1 / 2{ }^{\prime \prime} \\ 1 / 2^{\prime \prime}\end{array}\right.$ | $48^{\prime \prime}$ $48^{\prime \prime}$ $48^{\prime \prime}$ | $\begin{gathered} 96^{\prime \prime} \\ 120^{\prime \prime} \\ 144^{\prime \prime} \end{gathered}$ | Sheet <br> Sheet <br> Sheet. | $\begin{array}{r} 6 \\ 6 \\ 14 \end{array}$ | Crate <br> Crate <br> Box--- | $\begin{aligned} & 218 \\ & 235 \\ & 662 \end{aligned}$ | $\begin{aligned} & 15.21 \\ & 21.96 \\ & 39.05 \end{aligned}$ | Roof insulation. Wallboard. Celotex. |
| Glass substitute, reinforced |  | $\begin{aligned} & 36^{\prime \prime} \\ & 48^{\prime \prime} \end{aligned}$ | $\begin{aligned} & 100^{\prime} \\ & 198^{\prime} \end{aligned}$ | Square yard <br> Square yard | $\begin{aligned} & 331 / 3 \\ & 88 \end{aligned}$ | Carton_ <br> Box | $\begin{array}{r} 43 \\ 160 \end{array}$ | $\begin{aligned} & 0.93 \\ & 5.58 \end{aligned}$ |  |
| Roof coating, asphalt, fibrous, brushing consistency. | $\left\{\begin{array}{l} 5 \mathrm{gal} \\ 50 \mathrm{ga} \end{array}\right.$ | drum |  | Gallon <br> Gallon | $\begin{array}{r} 5 \\ 50 \end{array}$ | Can.-.- <br> Drum.- | $\begin{array}{r} 43 \\ 485 \end{array}$ | $\begin{array}{r} 1.08 \\ 11.67 \end{array}$ | Roof paint. |
| Wallboard, composition | $3 / 8^{\prime \prime}$ | $48^{\prime \prime}$ | $96^{\prime \prime}$ |  |  | -- | 141 |  | Wallboard. Insulating board. |

[^45]| Majot Divioione <br> （1） <br> （2） |  | $\begin{gathered} \substack{\text { Lotior } \\ \text { (3) }} \\ \hline \end{gathered}$ | Symbol | $\underset{(5)}{\text { color }}$ | ${ }_{\text {（6）}}^{\text {Name }}$ |  | Value as Bate Di－ rectly under Bu－ turninous Pavement $(B)$ <br> （B） | $\begin{gathered} \text { Potential } \\ \text { Froat } \\ \text { Action } \\ \text { (9) } \end{gathered}$ | $\begin{gathered} \text { Comprea abilluy } \\ \text { ondi } \\ \text { Expana on } \\ \text { (10) } \end{gathered}$ | Dramagc Choracterlatich （11） | Compacuon Equpment （12） |  |  | Subrrade Modutú Lb Perculn． （15） |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{array}{\|c\|} \text { COARSE } \\ \text { GRAINED } \\ \text { SOILS } \end{array}$ | GRAVEL <br> AND GRAVELLY solls |  | 80 | $\stackrel{\square}{\circ}$ | Well－graded gravela or g ravel－oand mixturas，utuct or no Anco | Excollear | Good | $\begin{aligned} & \text { None to very } \\ & \text { ollght } \end{aligned}$ | Almoat mono | Exccuent | Crawler－type tractor，rubber－ Ured equipincnt，otecl－whecled lired equipincont，otecl－whecled rollor | 125－140 | 60－80 | 300 or more |
|  |  | ${ }^{\text {ap }}$ | \％ |  | Poorly groded gravolo or grovel－a and mixtures，littic or no fineo | Good to oxcclle nt | Poor to falr | $\begin{array}{\|l} \text { None to very } \\ \text { sllght } \end{array}$ | Almoxt nonc | Excelloat | Crawler－type tractor，rubber－ rollor | $110-130$ | 25－60 | 300 or morc |
|  |  | $\mathrm{I}_{\mathrm{d}}$ | 6 | 颜 | Silty grovelo，$B$ rovel－and－ailt mixuroo | Good to axc．lit nt | Fars tog good | $\underbrace{\text { io }}_{\substack{\text { Slı } \\ \text { modium }}}$ | Vory Fl lght | Fair to poor | Rubber－tired oquipment， ehecpofoot roller；close con－ trol of monature | ${ }^{130-145}$ | 40－80 | 300 or mort |
|  |  |  | $\theta$ |  |  | Good | Poor |  | Stı ${ }^{\text {bht }}$ | Poor to procti－ cally Imporvious | Rubber－ured equpment， obecpafoot rollor | $120-140$ | $20-40$ | 200 w 300 |
|  |  | cc |  |  | Clayey grovele，gravet－oand－cloy mixtureo | Good | Poor | $\left\lvert\, \begin{aligned} & \text { Sught to } \\ & \text { modium } \end{aligned}\right.$ | SLIght | Poor to pract－ cally lmporvioue | Rubbor－tired oqupment， oboopaloot roller | 120.140 | 20.40 | 200 to 300 |
|  | sand <br> and <br> sandy <br> solls | sw |  | ジ̇ | Vell－nroded mando or gravelly aand＇s． hatll or no flneo | Good | Poor | $\begin{aligned} & \text { None to very } \\ & \text { ollght } \end{aligned}$ | Almot nonc | Excelient | Crawler－type tractor，rubber－ tlred equipment | 110.130 | 20.40 | 200 to 300 |
|  |  | sp |  |  | Pcoriy graded lands or gravelly oand．，hitle or no fince | Fair to good | Poot to cot outcoble | $\begin{aligned} & \text { Nono to vury } \\ & \text {-light } \end{aligned}$ | Almott nono | Excollent | Crouler－type tractor，rubber－ urod equipment | 100 －120 | 10.25 | 200 to 300 |
|  |  | $\begin{aligned} & 18 \\ & 1 \end{aligned}$ | 9．9．t | $\stackrel{3}{\stackrel{3}{a}}$ |  | Good | Poor |  | Vory ougbt | Far to poor | Rubber－tired cquipment heepfoot roller，clooe con trol of mostuture | 120－135 | 20.40 | 200 to 300 |
|  |  | ${ }^{s M} \vdash_{u}$ |  |  | Slity ando，sand－allt mixturce | Fatr to good | Not cw table |  | Sugbt to modium |  | Rubber－tired equipment． shece：foot roller | 105－130 | $10-20$ | 200 to 300 |
|  |  | sc |  |  | Clayoy a ando，sand－cley muxturoa | Fast to good | Not ©uitoble |  | $51 \mathrm{ll}_{\text {ght }}$ to medium | Poor to pract cally lmpirviove | Rubber－trod cquipment， ghoepsifoot roller | 105－130 | $10-20$ | 20010300 |
| fine graned solus | $\begin{gathered} \text { SLLTS } \\ \text { AND } \\ \text { CLAYS } \\ \text { LL } \quad \text { So } \end{gathered}$ | ML | － | 5ix | Inorganic alle and very ine alands， rock nour，oilly or clayey tine oand．s or cloyey ollto wlh olagbt plastucity | Falr to poor | Not tutoblo | $\begin{aligned} & \text { Medium to } \\ & \text { very } \mathrm{high}_{\mathrm{g}} \end{aligned}$ | Sught to madum | Fair to poor | Rubber－tured equpment， ohbepafoot roller，closo control of monsture | $100 \cdot 125$ | 5－15 | 1002000 |
|  |  | cL |  |  | Inorgande clrya of low to medium plaoticity，gravelly clayo，oandy clays，ollty cloya，lean claye | Fair to poor | Not outabic | $\begin{array}{\|l\|} \hline \begin{array}{l} \text { Modum to } \\ h_{\mathrm{g}} \end{array} \end{array}$ | Modum | Proctically lmperviouo | Rubber－tired equipment， hheepofoot roller | 100－125 | 5.15 | 100 to 200 |
|  |  | OL | $1 \%$ |  | Organce alto and organt adt－clays of low planiclity | Poor | Not sutabic | $\left.\right\|_{\substack{\text { modum } \\ w_{g h}}} ^{\text {Mo }}$ | Mcdium to high | Poor | Rubber－tired equipment， cherp－foot roller | $90-105$ | ${ }^{4.8}$ | 100 to 200 |
|  | $$ | ${ }^{\text {mh }}$ |  | 畐 | Inorganc sllts，micaccous or diotom sccous lino samdy or sllty solla，clavtic enlta | Poor | Not sumioble | $\begin{aligned} & \text { Mcdum to } \\ & \text { very hieh } \end{aligned}$ | ${ }^{\mathrm{H}} \mathrm{Lb}$ | Fair to poor | Sbeopstoot rolior | 80－100 | ${ }^{\text {4－8 }}$ | 100 20 200 |
|  |  | ch | $Y$ |  | Inorganic cloyn of bigb plantucity． tat clays | Poor to very poor | Not smable | Medium | $\mathrm{HHgh}^{\text {h }}$ | Practacally impe rviou | She cpat foot rollicr | 90.110 | ${ }^{3-5}$ | 50 to 100 |
|  |  | он |  |  | Organuc clayi of medium to tugb plasticlty，organic alla | Poor to very poor | Not suitabic | Modium | ${ }^{\text {High }}$ | $\begin{aligned} & \text { Practucally } \\ & \text { lmpervious } \end{aligned}$ | Sheopofoot roller | ${ }^{80} 105$ | ${ }^{3-5}$ | 50 10 100 |
| HGHLY ORGANIC SOLLS |  | Pt |  | － | Pcot and other Lughly organic soile | Not suttable | Not sutable | sulght | vory ugh | Falr to poor | Compaction not practical | $\cdot$ | － | － |

Noto：




amem intancoo，sovoral types of equipme

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Figure 105．Charactenstics of soils pertinent to roads and airfields．

| Major Divisions <br> (1) <br> (2) |  | $\begin{array}{\|c\|} \text { Letter } \\ \text { (3) } \end{array}$ | $$ | $\begin{aligned} & 1 \\ & \hline \begin{array}{l} \text { Color } \\ (5) \end{array} \\ & \hline \end{aligned}$ | $\begin{aligned} & \text { Nam } \\ & (6) \end{aligned}$ | Value for (7) | Permeability <br> (8) | Compaction Cbaracteristics <br> (9) | Std AASHO Max Unit Dry Weight Lb Per CuFt <br> (10) | Value for <br> Foundations <br> (11) | Requirements for Seepage Control (12) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| coarse GRAINED SOILS | gravel <br> AND gravelly soils | Gw | E 5itit | - | Well-graded gravelt or gravel-sand mixtures, little or no fines | Very stable, pervious shells of dikes and dams | k . $10^{-2}$ | Good, tractor, rubber-tired, steel-wheeled roller | 125-135 | Good bearing value | Positive cutoff |
|  |  | GP |  |  | Poorly-graded gravels or gravel-sand | Reasonably stable, pervious shells of dikes and dams | k $10^{-2}$ | Good, tractor, rubber-tired, steel-wheeled roller | 115-125 | Good bearing value | Positive cutoff |
|  |  | GM |  |  | Silty gravela, gravel-sand-allt mixtures | Reasonably stable, not particularly suited to shells, but may be used for impervioun corea or blankets | $\begin{aligned} & \mathrm{k}=10^{-3} \\ & \text { to } 10^{-6} \end{aligned}$ | Good, with close control, rubber-tired, shcep日foot roller | 120-135 | Good bearing value | Toe trench to none |
|  |  | cc | $0$ |  | $\begin{array}{l}\text { Clayey gravels, gravel-sand-clay } \\ \text { mixtures }\end{array}$ | Fairly stable, may be used for impervious core | $\begin{aligned} & k=10^{-6} \\ & \text { to }=10^{-8} \end{aligned}$ | Fair, rubber-tired, sheepsfoot roller | 115-130 | Good bearing value | None |
|  | sand <br> AND SANDY soILS | sw |  | \% | Well-graded sands or gravelly sands. Little or no fines | Very stable, pervious sections. slope protection required | k $10^{-3}$ | Good, tractor | 110-130 | Good bearing value | Upatream blanket and toe drainage or well |
|  |  | sp | : |  | Poorly-gradedsands or gravelly sands, little or no fines | Reasonably stable, may be used in dike section with flat slopes | k $10^{-3}$ | Good, tractor | 100-120 | Good to poor bearing value depending on density | Upatream blanket and toe drainage or welle |
|  |  | Sm | 19.6 | $\stackrel{\stackrel{\rightharpoonup}{g}}{\stackrel{\rightharpoonup}{0}}$ | Silty $\operatorname{sands,~sand-silt~mixtures~}$ | Fairly stable, not particularly suited to sbells, but may be uscd for impervious cores or dikes dikes | $\begin{aligned} & \mathrm{k}=10^{-3} \\ & \text { to } 10^{-6} \end{aligned}$ | Good, with close control, rubber-tired, sheepsfoot roller | 110-125 | Good to poor bearing value depending on density | Upatream blanket and toe drainage or wells |
|  |  | sc |  |  | Clayey sands, sand-silt mixtures | Fairly stable, use for impervious core for flood control structures | $\begin{aligned} & k=10^{-6} \\ & \text { to } \end{aligned}$ | Fair, sheepafoot roller, rubber tired | 105-125 | Good to poor bearing value | None |
|  | silts <br> and <br> clays <br> LL 50 | ML |  | $\begin{aligned} & \text { 5. } \\ & \text { ù } \end{aligned}$ | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with sligbt plasticity | Poor stability, may be used for embankmente with proper control | $\begin{gathered} k=10^{-3} \\ \text { to } 10^{-6} \end{gathered}$ | Good to paor, close control ensential, rubber-tired roller, sbeepafoat roller | 95-120 | Very poor, susceptible to liquefaction | Toe trench to none |
|  |  | CL |  |  | Inorganic clays of low to medium plasticlty, gravelly clays, sandy clays, silty clays, lean clays | Stable, impervious cores and blankets blankets | $\begin{aligned} \mathrm{k} & =10^{-6} \\ \text { to } & 10^{-8} \end{aligned}$ | Fair to good, sheepafoot roller. rubber tired | 95-120 | Good to poor bearing | None |
|  |  | OL |  |  | Organic silte and organic silt-clays of low plasticity | Not sutable for embankments | $\begin{aligned} & k=100^{-4} \\ & \text { to } \end{aligned}$ | Fair to poor, sheepsfoot roller | 80-100 | Fair to poor bearing, may have excessive settlements | None |
|  | $\begin{aligned} & \text { SILTS } \\ & \text { AND } \\ & \text { CLAYS } \\ & \text { LL } \quad 50 \end{aligned}$ | M ${ }^{\text {H }}$ |  | $\begin{aligned} & \stackrel{0}{\vec{m}} \end{aligned}$ | Inorganic silte, micaceous or diatomaceous fine sandy or silty soils, elastic silts | Poor atability, core of hydraule fill dam, not deairable in rolled fill construction | $\begin{aligned} & k=10^{-4} \\ & t o=10^{-6} \end{aligned}$ | Poor to very poar, sbeepsfoot roller | $70-95$ | Poor bearing | None |
|  |  | CH |  |  | Inorganic clays of high plasticity. fat clays | Fair stability with flat elopes. thin cores, blankets and dike sections | $\begin{aligned} & k=10^{-6} \\ & \text { to } 00^{-8} \end{aligned}$ | Fair to poor, sheepsfoot roller | 75-105 | Fair to poor bearing | None |
|  |  | он | EvA |  | Organic clays of medium to high plasticity, organic silts | Not suitable for embankments | $\begin{aligned} & k=10^{-6} \\ & \text { to } 10^{-8} \end{aligned}$ | Poor to very poor, bbeepsfoot rolle $r$ | 65-100 | Very poor bearing | None |
| Highly Organtc soils |  | Pt |  | 域 | Peat and other highly organic soils | Not used for construction |  | Compaction not practical |  | Remove from foundations |  |

Notes: 1. Values in columns 7 and 11 are for guidance only. Design abould be based on test results.
2. In column 9 , the equipment listed will ugually produce the deaired dengities with a reasor
2. In column, the equipment listed will usually produce the desired denside with a reabonable number of passes when moisture conditions and thickness of ilft are
3. Column 10. unit dry weights are for compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort.
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## 196. Nails and Spikes

a. Types and uses. See figure 107 for the sizes and uses of various types of nails.


Figure 107. Nails.

Table 206. Wire-Nail Sizes, Wire Gages, and Number Per Pound

| Size | Length (inehes) | Common |  | Siding |  | Finishing |  | Flooring |  | Fenee |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Gage | No.flb. | Gage | No./lb. | Gage | No./bb. | Gage | No./lb. | Gage | No./lib. |
| 2 d | 1 | 15 | 876 | 151/2 | 1,010 | 161/2 | 1,351 |  |  |  |  |
| 3 d | 1144 | 14 | 568 | 141/2 | 635 | 151/2 | 807 | -- |  | -- | -- |
| 4 d | $11 / 2$ | 121/2 | 316 | 14 | 473 | 15 | 584 | - |  | -- | -- |
| 5 d | 13/4 | 121/2 | 271 | 14 | 406 | 15 | 500 | - |  | 10 | 142 |
| 6 d | 2 | 11/2 | 181 | 121/2 | 236 | 13 | 309 | 11 | 157 | 10 | 124 |
| 7 d | 23/4 | 111/2 | 161 | 121/2 | 210 | 13 | 238 | 11 | 139 | 9 | 92 |
| $8{ }^{\text {d }}$ | $2^{1 / 2}$ | $10^{1 / 4}$ | 106 | 111/2 | 145 | 121/2 | 189 | 10 | 99 | 9 | 82 |
| 9d. | 23/4 | 10144 | 96 | 111/2 | 132 | 121/2 | 172 | 10 | 90 | 8 | 62 |
| 10d. | 3 | 9 | 69 | 101/2 | 94 | 111/2 | 121 | 9 | 69 | 7 | 50 |
| 12d. | $3{ }^{1 / 4}$ | 9 | 63 | ---- |  | 111/2 | 113 | 8 | 54 | 6 | 40 |
| 16 d | 3 \%2 | 8 | 49 | --- |  | 11 | 90 | 7 | 43 | 5 | 30 |
| 20d. | 4 | 6 | 31 |  |  | 10 | 61 | 6 | 31 |  |  |
| 30 d | 41/2 | 5 | 24 |  |  |  |  |  |  |  |  |
| 40d. | 5 | 4 | 18 |  |  |  |  |  |  |  |  |
| 50 d | 51/2 | 3 | 15 |  |  |  |  |  |  |  |  |
| 60d. | 6 | 2 | 11 |  |  |  |  |  | - |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

Nute 1. To avoid splitting, nail diameters should not execed $1 / 7$ of the thickness of lumber to be mailed.
Note 2. Gages in above table are U.S. Steel Wire Gage. Fractional gages are:

| Gage..-...........--- | 101/4 | 1032 | 1126 | 1242 | 1412 | 1512 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Diameter, inches...- | 0.1314 | 0.1278 | 0.1130 | -0.0985 | 0.0760 | 0.0673 |

c. Standard Barbed Roofing Nails.

| Size and length_ | 3/4' ${ }^{\prime \prime}$ | $7 / 8^{\prime \prime}$ | $1^{\prime \prime}$ | 1/8' ${ }^{\prime \prime}$ | $114^{\prime \prime}$ | 13/8' ${ }^{\prime \prime}$ | 11/2' | $13 / 4^{\prime \prime}$ | $2^{\prime \prime}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Gage-.------ | 13 | 12 | 12 | 12 | 11 | 11 | 10 | 10 | 9 |
| Number per pound------ | 714 | 469 | 411 | 365 | 251 | 230 | 176 | 151 | 103 |

d. Standard Round Spikes, Flat Head, Diamond Point.

| Size. | 10d | 12d | 16d | 20d | 30d | 40d | 50d | 60d | 7' | $8^{\prime \prime}$ | $9^{\prime \prime}$ | 10' | $12^{\prime \prime}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Length (inches).- | 3 | 334 | 3126 | 4 | 4129 | 5 | 512 | 6 | 7 | 8 | 9 | 10 | 12 |
| Gage.....-------- | 6 | 6 | 5 | 4. | 3 | 2 | 1 | 1 | $516^{\prime \prime}$ | $38^{\prime \prime}$ | $38^{\prime \prime}$ | $38^{\prime \prime}$ | $38^{\prime \prime}$ |
| Number per pound $\qquad$ | 41 | 38 | 30 | 23 | 17 | 13 | 10 | 9 | 7 | 4 | 31/2 | 3 | 24,2 |

e. Nails and Spikes Stocked in Oversea Depots (Fed. Spec. FF-N-103 and $\mathrm{FF}-\mathrm{N}-105$ ) (SM 5-3). See table 207.

## 197. Wood Screws

The weight of flat-head bright wood screws, in pounds per gross, is given in table 208. The table also indicates the sizes manufactured. Sizes stocked in oversea depots are in italics.

## 198. Staples

a. Wire staples, fence steel, galvanized, are stocked in oversea depots in two sizes, 78 -inch and $1 \frac{1}{2}$-inch, both of number 9 wire.
b. Cut-point staples (fig. 108) are furnished in five sizes for various cables and conductors.

## 199. Lag Screws

a. Dimensions. Diameters and threads per inch of lag screws are given in table 209 ; lengths of threaded portions of lag screws are given in table 210.

Table 207. Nails and Spikes Stocked in Oversea Depots
(Federal Specifications FF-N-103 and FF-N-105)

|  |  |  |  |  | marks |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Description | Unit of <br> issue | $\underset{\text { ability }}{\text { Expend- }}$ | $\begin{array}{\|l\|l\|} \hline \text { Illustration } \\ \text { No. } \end{array}$ | $\begin{array}{\|c\|} \text { Repair } \\ \text { parts sup- } \\ \text { port code } \end{array}$ | $\begin{aligned} & \text { Category of } \\ & \text { issue } \end{aligned}$ |
| NAIL, BOX, GENERAL PURPOSE, wire, steel, smooth shank, diamond point, flat head, Fed FF-N-105, box nail type: | lb | X |  |  |  |
| Cement coated finish: |  |  |  |  |  |
| $2 \mathrm{~d}, 1 \mathrm{in} . \mathrm{lg}, 0.058 \mathrm{in}$. dia shank, 0.172 in . dia head_ |  |  |  |  | 5 |
| 3d, $11 / 8 \mathrm{in}$. $\lg , 0.063 \mathrm{in}$. dia shank, 0.188 in . dia head | lb | X |  |  | 5 |
| $4 \mathrm{~d}, 13 / 8 \mathrm{in} . \lg , 0.067 \mathrm{in}$. dia shank, 0.203 in . dia head. | lb | X |  |  | 2, 5 |
| $5 \mathrm{~d}, 15 / 8 \mathrm{in}$. $\lg , 0.072 \mathrm{in}$. dia shank, 0.219 in . dia head. | lb | X |  |  |  |
| $6 \mathrm{~d}, 17 / \mathrm{in} . \lg , 0.086 \mathrm{in}$. dia shank, 0.250 in . dia head. | lb | X |  |  | 2, 5 |
| $7 \mathrm{~d}, 2 \frac{1}{8} \mathrm{in}$. $\lg , 0.086 \mathrm{in}$. dia shank, 0.250 in . dia head- | lb | X |  |  | 5 |
| $8 \mathrm{~d}, 23 / 8 \mathrm{in}$. $\lg , 0.099 \mathrm{in}$. dia shank, 0.266 in . dia head | lb | X |  |  | 2, 5 |
| $9 \mathrm{~d}, 25 / 8 \mathrm{in}$. $\mathrm{lg}, 0.099 \mathrm{in}$. dia shank, 0.266 in . dia head. | lb | X |  |  | 5 |
| $10 \mathrm{~d}, 27 / 8 \mathrm{in}$. $\mathrm{lg}, 0.113 \mathrm{in}$. dia shank, 0.297 in . dia head | lb | X |  |  | 2, 5 |
| Protective finish, not applicable: | 1 b | X |  |  |  |
| $4 \mathrm{~d}, 1 \frac{1}{2} \mathrm{in} . \mathrm{lg}, 0.080 \mathrm{in}$. dia shank, 0.219 in . dia head. |  |  |  |  | 2, 5 |
| $5 \mathrm{~d}, 13 / \mathrm{in} . \lg , 0.080 \mathrm{in}$. dia shank, 0.219 in . dia head. | lb | X |  |  | 5 |
| $6 \mathrm{~d}, 2 \mathrm{ill} . \mathrm{lg}, 0.099 \mathrm{in}$. dia shank, 0.266 in . dia head.- | lb | X | - |  | 5 |
| $7 \mathrm{~d}, 214 \mathrm{in}$. $\lg , 0.099 \mathrm{in}$. dia shank, 0.266 in . dia head. | lb | X |  |  | 5 |
| $8 \mathrm{~d}, 2 \frac{1}{2} \mathrm{in} . \lg , 0.113 \mathrm{in}$. dia shank, 0.297 in . dia head. | lb | X |  |  | 2, 5 |
| $10 \mathrm{~d}, 3 \mathrm{in} . \mathrm{lg}, 0.128 \mathrm{in}$. dia shank, 0.313 in . dia head. | 1 b | X |  |  | 2, 5 |

NAIL, BOX, NAILING MACHINE, wire, steel, cement coated finish, Ref Dwg Group 22, sections B, D, E, smooth shank, style 16, diamond point, style 7:
Flat countersunk head, style 18, Fed FF-N-105, cement coated countersunk head nail type:

 $5 \mathrm{~d}, 15 / 8 \mathrm{in} . \lg , 0.026 \mathrm{in}$. dia sliank, 0.219 in . dia headl $6 \mathrm{~d}, 17 / 8 \mathrm{in} . \mathrm{lg}, 0.092 \mathrm{in}$. dia shank, 0.234 in . dia headlb

$8 \mathrm{~d}, 23 / 8 \mathrm{in}$. $\mathrm{lg}, 0.113 \mathrm{in}$. dia shank, 0.266 in . dia head
lb

$12 \mathrm{~d}, 31 / 8 \mathrm{in} . \lg , 0.135 \mathrm{in}$. dia sliank, 0.313 in . dia headlb $20 \mathrm{~d}, 33 / 4 \mathrm{in}$. lg, 0.177 in . dia shank, 0.375 in . dia liead $30 \mathrm{~d}, 41 / 4 \mathrm{in} . \mathrm{lg}, 0.192 \mathrm{in}$. dia shank, 0.406 in . dia head $40 \mathrm{~d}, 43 / 4 \mathrm{in}$. lg, 0.207 in . dia shank, 0.438 in . dia headb $60 \mathrm{~d}, 5 \frac{3}{4} \mathrm{in} . \lg , 0.244 \mathrm{in}$. dia shank, 0.500 in . dia head
Flat head, style 14, Fed FF-N-105, cement coated standard, nail type:
$2 \mathrm{~d}, 1 \mathrm{in} . \mathrm{lg}, 0.063 \mathrm{in}$. dia shank, 0.172 in . dia head.

$4 \mathrm{~d}, 13 / 8 \mathrm{in} . \lg , 0.080 \mathrm{in}$. dia shank, 0.219 in . dia head

$$
5 \mathrm{~d}, 15 / 8 \mathrm{in} . \mathrm{lg}, 0.086 \text { in. dia shank, } 0.234 \text { in. dia head }
$$

$6 \mathrm{~d}, 17 / 8 \mathrm{in} . \lg , 0.092 \mathrm{in}$. dia shank, 0.250 in . dia head

$$
\begin{align*}
& 7 \mathrm{~d}, 21 / 8 \mathrm{in} . \lg , 0.039 \mathrm{in} . \text { dia shank, } 0.266 \mathrm{in} . \text { dia head } \\
& 8 \mathrm{~d}, 23 / 8 \mathrm{in} . \lg , 0.113 \mathrm{in} . \text { dia shank, } 0.281 \text { in. dia head }
\end{align*}
$$

$10 \mathrm{~d}, 27 / 8 \mathrm{in} . \mathrm{lg}, 0.121 \mathrm{in}$. dia shank, 0.297 in . dia head
lb
NAIL CASING, wire steel, Ref Dwg Group 22, sections B, D, E, smooth shank, style 18, diamond point, style 16, flat countersunk head, style 13, Fed FF-N-105:

4d, $1 \frac{1}{2} \mathrm{in}$. $\lg$
$6 \mathrm{~d}, 2 \mathrm{in} . \mathrm{lg}_{-}$
lb
8d, $21 / 2 \mathrm{in} . \mathrm{lg}$
lb
NAIL, CLOUT, cut, steel, Ref Dwg Group 22, sections B, D, E; tapered shank, style 19, blunt point, style 2, flat head, style 14, Fed FF-N-103:
$3 / 4 \mathrm{in}$. $\lg$
$1 \mathrm{in} . \lg$


| Deseription | $\begin{aligned} & \text { Unit of } \\ & \text { issuc } \end{aligned}$ | $\underset{\substack{\text { Expend- } \\ \text { ability }}}{ }$ | $\underset{\substack{\text { Illustration } \\ \text { No. }}}{ }$ | Remarks |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | $\begin{aligned} & \text { Repair } \\ & \text { parts sup- } \\ & \text { port codid } \end{aligned}$ | $\begin{gathered} \text { Catcerory of } \\ \text { issuo } \end{gathered}$ |
| NAIL, COMMON, wire, steel, smooth shank, diamond point, flat head, Fed FF-N-105: $2 \mathrm{~d}, 1 \mathrm{in} . \lg$ - |  |  |  |  |  |
|  | lb | X |  |  | 1,2,5 |
| 3d, $1^{1 / 4} \mathrm{in} .1 \mathrm{lg}-$ | lb | X |  |  | 2, 4 |
| $4 \mathrm{~d}, 11 / 2 \mathrm{in} .1 \mathrm{lg}$ | lb | X |  |  | 1, 2, 4 |
| $5 \mathrm{~d}, 13 / 4 \mathrm{in} . \mathrm{lg}$ - | lb | X |  |  |  |
| $6 \mathrm{~d}, 2 \mathrm{in} . \mathrm{lg}$ - | lb | X |  |  | 1, 2, 4 |
| 7d, $21 / 4 \mathrm{in}$. lg - | lb | X |  |  | 5 |
| $8 \mathrm{~d}, 21 / 2 \mathrm{in}$. lg - | lb | X |  |  | 1, 2, 4 |
| $9 \mathrm{~d}, 23 / \mathrm{in}$. lg - | lb | X | ----- |  | - 5 |
| $10 \mathrm{~d}, 3 \mathrm{in} .1 \mathrm{lg}-$ | lb | X |  |  | 1, 2, 4, 8 |
| 12d, $31 / 4 \mathrm{in}$. lg | lb | X |  |  | 1, 2, 4, 8 |
| $16 \mathrm{~d}, 3 \% \mathrm{in}$. lg | lb | X |  |  | 1, 2, 4 |
| 20d, 4 in . lg - | lb | X | --- |  | 1, 2, 4 |
| 30d, $41 / 2 \mathrm{in}$. lg - | lb | X |  |  | 1, 2, 4 |
| $40 \mathrm{~d}, 5 \mathrm{in} . \mathrm{lg}$ - | lb | X |  |  | 1, 2, 4, 8 |
| 50d, 51/2 in. lg- | lb | X |  |  | 2, 4 |
| $60 \mathrm{~d}, 6 \mathrm{in} . \mathrm{lg}$ - | lb | X |  |  | 1, 2, 4, 8 |
| Zinc coated finish: |  |  |  |  | 1,2, 4,8 |
| $4 \mathrm{~d}, 1 \frac{1}{2}$ in. lg | lb | x |  |  | 1, 2 |
| 20d, 4 in .1 lg - | lb | X |  |  |  |
| NAIL, COMPOSITION ROOFING, wire, stecl, zinc coated finish, Rcf Dwg Group 22, sections B, D, E, barbed shank, style 1, diamond point, style 7, flat head, style 14, Fed FF-N-103, roofing nail type: |  |  |  |  |  |

$7 / 8 \mathrm{in} . \lg$.
$1 \mathrm{in} . \mathrm{lg}$
NAIL, DOUBLE HEADED, wire, steel, Ref Dwg Group 22, sections B, D, E, smooth shank, style 16, diamond point, style 7, duplex head, style 11, Fed FF-N-105, duplex head nail type:
$8 \mathrm{~d}, 23_{4}^{\prime} \mathrm{in}$. lg . from under lower head to pcint, $1 / 4 \mathrm{in}$. lg . between heads, 0.131 in . dia shank.
$10 \mathrm{~d}, 23 / 4 \mathrm{in}$. Ig. from under lower head to point, $3 / 16 \mathrm{in}$. Ig. betiveen heads, 0.148 in . dia shank.
$16 \mathrm{~d}, 3 \mathrm{in}$. lg . from under lower head to point, $3 / 8 \mathrm{inl}$. lg . between heads, 0.182 in . dia shank.
NAIL, DRIVE SCREW, wire, steel, Ref Dwg Group 22, scetions B, D, E, screw shank, style 11, needle point, style 9 , oval head style $43,13 / 4 \mathrm{in} . \lg , 0.177 \mathrm{in}$. dia. shank, Signode Co. or equal.
NAIL, FINISHING, wire, steel, Ref. Dwg. Group 22, seetions B, D, E, smooth shank, style 11, needle point, style 9 , oval head style $43,13 / 4 \mathrm{in} . \mathrm{lg}, 0.177 \mathrm{in}$. dia. shank, Signode Co. or equal.
NAIL, FINISHING, wire, steel, Ref. Dwg. Group 22, seetions B, D, E, smooth shank, style 16, diamond point, style 7, brad head, style 2, Fed FF-N-105:
3d, $11 / 4 \mathrm{in}$. lg
4d, 1 1/2 in. lg
$6 \mathrm{~d}, 2 \mathrm{in}$. lg -
8d, $21 / 2 \mathrm{in}$. lg

NAIL, FOUNDRY, wire, steel, protective finish not applicable, Ref. Dwg. Group $21 / 2$, seetions B, D, E, smooth shank, style 16, diannond point, style 7, flat head, style $14,0.162$ in. dia. shank, 0.500 in. dia. head, Fed FF-N-101:

1 in . lg
2 in. $\lg$
$3 \mathrm{in} . \mathrm{lg}$
lb
1 b
lb


Table 208. Sizes and Weights of Wood Screws

| Size | $1 / 4$ | 3/8 | 32 | 5/8 | $8 / 4$ | 78 | 1 | 11/4 | 11/2 | 13/4 | 2 | 21/4 | 21/2 | 23/4 | 3 | 3112 | 4 | 41/2 | 5 | 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0 | 0. 024 | 0.040 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | . 037 | . 060 | 0.07 | 0.09 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | . 052 | . 085 | 10 | . 12 | 0. 13 | 0. 15 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 | . 070 | . 101 | . 13 | . 15 | . 17 | 20 | 0. 26 | 0. 30 |  |  |  |  |  |  |  |  |  |  |  |  |
| 4 | . 092 | . 13 | . 16 | . 19 | . 22 | 26 | 29 | . 37 | 0. 44 |  |  |  |  |  |  |  |  |  |  |  |
| 5 |  | . 16 | . 20 | . 25 | . 29 | . 33 | . 38 | . 48 | . 56 | 0. 64 | 0. 73 |  |  |  |  |  |  |  |  |  |
| 6 |  | . 20 | . 25 | . 30 | . 36 | . 41 | . 46 | . 59 | . 68 | . 79 | . 90 | 1. 10 | 1. 13 | 1.25 | 1. 35 |  |  |  |  |  |
| 7 |  | . 24 | . 31 | . 37 | . 43 | . 50 | . 56 | . 72 | . 84 | . 96 | 1. 10 | 1. 23 | 1. 37 | 1. 53 | 1. 64 |  |  |  |  |  |
| 8 |  | . 29 | . 37 | . 44 | . 56 | . 59 | . 67 | . 85 | . 99 | 1. 15 | 1. 32 | 1. 46 | 1. 64 | 1. 82 | 1. 96 | 2. 25 | 2. 57 |  |  |  |
| 9 |  | . 34 | . 44 | . 52 | . 61 | . 70 | . 79 | . 99 | 1. 17 | 1. 35 | 1. 54 | 1. 71 | 1. 93 | 2. 12 | 2. 29 | 2. 63 | 3.00 |  |  |  |
| 10 |  |  | . 51 | . 60 | . 71 | . 81 | . 92 | 1.16 | 1.86 | 1. 57 | 1. 78 | 2. 00 | 2. 24 | 2. 46 | 2. 67 | 3. 07 | 3. 48 |  |  |  |
| 11 |  |  | . 58 | . 69 | . 82 | . 94 | 1. 07 | 1.34 | 1. 56 | 1. 80 | 2. 04 | 2. 32 | 2. 59 | 2. 85 | 3. 09 | 3. 53 | 4.01 |  |  |  |
| 12 |  |  | . 66 | . 79 | . 93 | 1. 07 | 1. 21 | 1. 52 | 1. 78 | 2. 07 | 2. 35 | 2. 64 | 2. 94 | 3. 25 | 3. 52 | 4. 01 | 4. 57 | 5. 14 | 5. 80 |  |
| 13 |  |  |  | . 90 | 1. 05 | 1. 21 | 1.37 | 1. 72 | 2. 01 | 2. 34 | 2. 67 | 2. 97 | 3. 33 | 3. 67 | 3. 97 | 4. 53 |  |  |  |  |
| 14 |  |  |  | 1. 03 | 1. 18 | 1. 36 | 1. 54 | 1.93 | 2. 26 | 2. 63 | 2. 99 | 3.33 | 3. 72 | 4.10 | 4. 44 | 5. 08 | 5. 75 | 6. 25 | 7.34 | 8. 60 |
| 15 |  |  |  |  | 1.32 | 1.53 | 1. 74 | 2. 15 | 2. 54 | 2. 92 | 3. 34 | 3. 72 | 4. 16 | 4. 56 | 4. 94 | 5. 65 |  |  |  |  |
| 16 |  |  |  |  | 1. 47 | 1. 71 | 1. 92 | 2. 39 | 2. 82 | 3. 25 | 3. 73 | 4. 14 | 4. 62 | 5. 06 | 5. 98 | 6. 28 | 7. 10 | 8. 09 | 9.04 | 10. 70 |
| 17 |  |  |  |  |  |  | 2. 12 | 2. 65 | 3. 13 | 3.61 | 4. 13 | 4. 58 | 5. 13 | 5. 61 | 6. 07 | 6. 95 |  |  |  |  |
| 18 |  |  |  |  |  |  | 2. 34 | 2. 95 | 3. 45 | 4. 00 | 4. 53 | 5. 05 | 5. 65 | 6. 18 | 6. 70 | 7. 68 | 8. 67 | 9.89 | 11. 10 | 12. 90 |
| 20 |  |  |  |  |  |  |  | 3. 50 | 4. 10 | 4. 78 | 5. 40 | 6.03 | 6. 76 | 7. 36 | 7. 98 | 9. 13 | 10. 40 | 11.80 | 13. 40 | 15. 40 |
| 22 |  |  |  |  |  |  |  | 4.13 | 4. 86 | 5. 60 | 6.35 | 7. 04 | 7. 90 | 8. 55 | 9. 35 | 10. 70 | 12. 20 | 13. 80 | 15. 50 | 18. 30 |
| 24 |  |  |  |  |  |  |  | 4. 78 | 5. 65 | 6. 52 | 7. 39 | 8. 26 | 9. 13 | 10. 01 | 10. 81 | 12. 50 | 14. 15 | 16. 20 | 18.15 | 21. 20 |
| 26 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 12. 50 | 14. 40 | 16. 25 | 18. 60 | 20. 80 | 24. 40 |
| 28 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 18. 40 | 21. 25 | 23.75 | 27. 70 |
| 30 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 21.00 | 24. 30 | 27. 30 | 31. 80 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



Figure 108. Cut-point staples.

Table 209. Diameters and Threads Per Inch of Lag Screws

|  | Lag screw diameters |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1/4 | 966 | 3/8 | 3/6 | 1/2 | 56 | $3 / 4$ | 7/6 | 1 |
| Diameter at root of thread, inches. | 0. 173 | 0. 227 | 0. 265 | 0. 328 | 0. 371 | 0. 471 | 0. 579 | 0. 683 | 0. 780 |
| Diameter of pilot hole for threads, inches. | 5/32 | 3/16 | 1/4 | 5/10 | 3/8 | 7/16 | 9/16 | 5/8 | 3/4 |
| Threads per inch. | 10 | 9 | 7 | 7 | 6 | 5 | 41/2 | 4 | $31 / 2$ |

b. Sizes Stocked in Oversea Depots.
(1) Standard lag screws, cone point: $1 / 4-$ by 1 -inch, $3 / 8-$ by 4 -inch, $1 / 2$ - by 2 -inch, $1 / 2$ - by 4 -inch, $5 / 8$ - by 4 -inch, and $3 / 4$ - by 4 -inch.
(2) Gimlet point: black, $3 / 8-$ by 3 -inch; galvanized $1 / 2$ - by $4 \frac{1}{2}$-inch.

Table 210. Lengths of Threaded Portions of Lag Screws


1 Measured from underside of head to point.
200. Bolts, Machine, American Standard Regular

Table 211. Bolt Sizes and Threads

| Bolt (inches) | Number of threads per inch: | Diameter at root of thread (inclies) | Area at root of thread (square inches) | Short diameter of square head (inches) | Short diameter of nut (square or hexagon) (inches) | Height of nut (inclies) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1/4- | 20 | 0. 185 | 0. 027 | 3/8 | 16 | 1/4 |
| $3 / 8$ | 16 | . 294 | . 068 | 9/16 | 5/8 | 5/16 |
| 1/2 | 13 | . 400 | . 126 | $3 / 4$ | 13/16 | 7/16 |
| 5/8- | 11 | . 507 | . 202 | $15 / 16$ | 1 | 96 |
| 3/4 | 10 | . 620 | . 302 | 1/8 | 11/8 | 11/16 |
| 7/8- | 9 | 731 | . 419 | 15/16 | 1516 | $3 / 4$ |
| 1 | 8 | . 838 | . 551 | 11/2 | 11/2 | 7/8 |
| 11/8- | 7 | . 939 | . 693 | 111/6 | $111 / 16$ | 1. |
| 11/4- | 7 | 1. 064 | . 890 | 17\% | 178 | $11 / 8$ |
| $13 / 8$ | 6 | 1. 158 | 1. 054 | 21/10 | 21/10 | 11/4 |
| 11/2- | 6 | 1. 283 | 1. 294 | 2/4 | 21/4 | 1510 |
| $15 / 8$ |  |  |  | 27/10 | 29/16 | $15 / 8$ |
| 13/4- | 5 | 1. 490 | 1. 744 | 25\% | 23 3, | $13 / 4$ |
| 178 |  |  |  | $2^{13 / 16}$ | $2^{15 / 18}$ | 17\% |
| 2 | 41/2 | 1. 711 | 2. 300 | 3 | 31/8 | 2 |
| 21/4 | $41 / 2$ | 1. 961 | 3.031 | 33/8 | 31/2 | 21/4 |
| 21/2 | 4 | 2. 175 | 3. 716 | $33 / 4$ | 37/8 | 21/2 |
| 23/4 | 4 | 2. 425 | 4. 619 | 41/8 | 41/4 | 23/4 |
| 3. | 4 | 2. 675 | 5. 621 | 4112 | 45/8 | 3 |

[^46]
## 201. Manila Rope

a. Weight and Strength. Table 212 shows the unit weights and breaking strengths of the most commonly used sizes of manila rope (natural color, three-strand, oil-treated).
b. Sheave Diameters. Within the range of sizes shown in table 212, sheave diameter should be not less than eight times the diameter of the rope.

Table 212. Manila Rope

|  | Circumference (inches) | Feet per pound | TBreaking Strength (pounds) |
| :---: | :---: | :---: | :---: |
| $3 / 4$ |  | 50.0 | 600 |
| 1 |  | 34.5 | 1, 000 |
| 11/8 |  | 24. 4 | 1, 359 |
| 11/2 |  | 13.3 | 2, 650 |
| 2 |  | 7. 5 | 4, 400 |
| 214 |  | 6. 0 | 5, 400 |
| $21 / 2$ |  | 5. 13 | 6,500 |
| $23 / 4$ |  | +. $5+$ | 7,700 |
| 3. |  | 3.71 | 9, 000 |

## 202. Sand, Gravel, Crushed Rock

Tables 213 through 218 give data on sand, gravel, and crushed rock used as construction materials.

Table 213. Linear Feel of Spread of Gravel and Crushed Rock To Produce 1-Inch Thickness

| Widtb, feet | Thickness |  | Lincar feet of spread $1 \mathrm{cu} . \mathrm{yd}$. |
| :---: | :---: | :---: | :---: |
|  | Inches | Condition ${ }^{1}$ |  |
| 10. | 1 | ¢Loose_ | 32. 4 |
|  |  | Compicted.... | 25. 9 |

[^47]Example: Length of spread for $2 \frac{1}{2}$-cubic yard truckload of gravel to produce 4 -inch compacted thickness 22 feet wide is:

$$
L=25.9 \times \frac{10}{22} \times 2.5 \times 1 / 4=7.3 \text { feet. }
$$

Table 214. Cubic Yards, Loose Measure, Gravel or Crushed Rock Required Per Linear Unit of Road to Produce 1-Inch Thickness

| Width in feet | Condition ${ }^{1}$ | Length of road section |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | 100 ft . | 100 yd . | 1 mile |
| 10 | $\{$ Loose | 3. 09 | 9. 26 | 162. 9 |
|  | Compacted | 3. 86 | 11. 57 | 203. 6 |

${ }^{1}$ Ratio of loose thlckness to compacted thickness assumed to be 1.25 to 1 .
Example: Quantity required for 4 -inch compacted course on 350 yards of road 22 -feet wide is:
$Q=11.57 \times \frac{22}{10} \times \frac{4}{1} \times \frac{350}{100}=356.4$ cubic yards, loose measure.
Table 215. Square Yards per Hundred Running Feet, per Hundred Yards, and Per Mile for Various Surface Widths .

| Width in feet | Number of square yards- |  |  |
| :---: | :---: | :---: | :---: |
|  | Per 100 ft . | Per 100 yd . | Per mile |
| 9 | 100.0 | 300.0 | 5, 280 |
| 10 | 111. 1 | 333.3 | 5, 867 |
| 12 | 133.3 | 400. 0 | 7, 040 |
| 16 | 177.8 | 533. 3 | 9, 387 |
| 18 | 200. 0 | 600.0 | 10, 560 |
| 20 | 222. 2 | 666.7 | 11, 734 |
| 22 | 244.4 | 733.3 | 12,907 |

Table 216. Pounds of Aggregate Required per Square Yard for Various Thicknesses. of Compacted Layers

| Weight of $1 \mathrm{cu} . \mathrm{yd}$. dry loose aggregate, pounds | Thickness of compacted layer ${ }^{1}$ |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $3 / 2 \mathrm{~mm}$. | $3 / 4 \mathrm{in}$. | 1 in . | 2 in . | 232 in . | 3 in . |
| 2,100-------------- | 37 | 56 | 74 | 149 | 186 | 223 |
| 2,200 | 38 | 58 | 77 | 154 | 199 | 231 |
| 2,300 | 40 | 60 | 80 | 164 | 205 | 246 |
| 2,400 | 41 | 61 | 82 | 164 | 205 | 246 |
| 2,500 | 42 | 63 | 84 | 169 | 211 | 253 |
| 2,600 | 43 | 65 | 87 | 173 | 217 | 260 |
| 2,700. | 44 | 67 | 89 | 178 | 222 | 267 |
| 2,800. | 45 | 68 | 91 | 182 | 227 | 273 |
| 2,900. | 47 | 70 | 93 | 186 | 233 | 279 |
| 3,000--------------- | 47 | 71 | 95 | 190 | 237 | 285 |

[^48]Table 217. Average Weights of Aggregates and Soils Per Cubic Yard

| Description | Loose pounds | Compaeted pounds |
| :---: | :---: | :---: |
| Earth | 2, 100 | 2, 700 |
| Coarse material macadam aggre | 2, 500 | 3, 100 |
| Graded sand | 2,600 | 3, 300 |
| Graded gravel or crushed rock | 2,800 | 3, 600 |

Table 218. Weight of Crushed Rock

| Type of rock | Weight of crushed rock |  |
| :---: | :---: | :---: |
|  | Pounds per eubic foot | Tons per cubic yard |
| Trap rock | 107 | 1. 45 |
| Granite. | 97 | 1. 31 |
| Limestone. | 100 | 1. 35 |
| Shale_ | 95 | 1. 28 |
| Gravel | 105 | 1. 41 |

## Section VII. MASONRY

## 203. Stone Masonry

$a$. Ashlar. This is the best type of stone masonry and the type used for work requiring great strength and stability. It is charactcrized by carefully bonded and fitted stones set on level beds and laid with joints varying from $1 / 8$ to $1 / 4$ inch thick for architectural work and from $1 / 4$ to $1 / 2$ inch thick for railroad masonry.
b. Squared-Stone Masonry. Usually constructed as broken-coursc work, this type is fitted less carcfully than ashlar, more carcfully than rubble. Well-built squared-stone masonry normally includes the highest types used in military construction.
c. Rubble. Rubble masonry is built with a minimum of dressing, with joints unevenly courscd, or in a completelv irregular pattern. Stones arc lapped for bond and many stoncs extend through a wall to bond it transversely. If built carefully, with all interstices completely filled with good cement mortar and bedded spalls, rubble masonry has ample strength and durability for ordinary structures.

## 204. Brick Masonry

a. Types of Brick.
(1) Common brick, normally 8 by $33 / 4$ by $23 / 16$ inches are used in all brickwork unless other types are specifically mentioned. They are typically kiln-burned clay or clay-and-shale mix-
tures, but are also made of a sand-lime combination, steam cured, or of sand and portland cement, moist cured.
(2) Paving brick. Vitrified paving brick and paving blocks, very hard and durable, are used in any structure in which these qualities are required.
(3) Firebrick, laid in a thin grout of fire clay, are used in furnace linings and other refractory service.
b. Brick Quantities. In common brick masonry, about $63 / 4$ brick are required per square foot of wall 1 brick in thickness; 20 brick per cubic foot of masonry.
c. Rate of Laying Brick. A skilled bricklayer can lay 1,200 or more brick per 8 -hour day in straight walls 3 bricks or more in thickness; 200 to 600 brick in thinner walls or in work having many corners, angles, or openings. These maximum rates are not normally attained in peacetime construction in this country.

## 205. Hollow-Tile and Concrete-Block Masonry

These materials are used in lightweight walls and partitions to provide thicknesses necessary for stability or to provide stable backing for 4 -inch brick facing. Usual sizes and types are as follows:
a. Hollow Tile.
(1) For backup and bearing-wall purposes, many sizes and types have been developed, typically to provide hollow-tile wall thickncsses of 8 inches and 12 inches. A common type is the 6 -cell hollow tile 8 by 12 inches, weighing about 36 pounds. It can be used for walls of either 8- or 12 -inch thickness.
(2) For partitions, 3 -cell tile with 12 - by 12 -inch faces are made for 3 -, 4 -, and 6 -inch wall thicknesses.
b. Concrete Blocks. These are typically 12 or 16 inches long, 8 inches high, and made for wall thicknesses of 4,8 , and 12 inches. Walls 12 inches thick are used for foundation walls for light structures, the 8 -inch thickness for cxterior walls above grade and for piers, and the 4 -inch thickness for partitions.

206. Unit Weights | Weunht in per |
| :---: |
| cubic foot |




Hollow-tile or concrete-block masonry
40 to 70

## 207. Mortar

For 1 cubic yard of $1: 3$ cement mortar with 10 percent of the cement replaced by lime putty, about 880 pounds of portland cement and 40 pounds of hydrated lime are added to 1 cubic yard of sand, damp and loose measure. More sand, up to a total of 2 cubic yards, is added if less strength is needed. For a 1-bag batch, the usual quantities are

94 pounds of cement, 5 pounds of hydrated lime, and 3 to 5 cubic feet of sand. The number of cubic yards of mortar per hundred square feet of wall of various materials are as follows:


## Section VIII. EXPLOSIVES

## 208. General

TM 9-1910 presents basic data on the subject. FM 5-25 summarizes the characteristics of explosives and their uses. TM 5-220 includes obstacle removing by explosives. TM 9-1946 describes demolition materials and their use. FM 5-34 gives explosives and demolition data for field use.

## 209. Weights of Explosives

Table 219 lists certain standard explosive charges with their net weights and package weights. For further details see SM 9-5-1375.

Table 219. Weights of Certain Explosive Charges

| Item | Net weight | Package weight |
| :---: | :---: | :---: |
| Charge, demolition, block, M5A1.-- | 21/2 lbs | 75 lbs (24 charges) |
| $1 \frac{1}{2} \mathrm{lb}$ TNT. | 1/2 lb | 63 lbs ( 100 charges ) |
| 1 lb TNT | 1 lb | 63.7 lbs ( 50 charges) |
| 8 lbs TNT | 8 lbs | 84 lbs ( 8 charges) |

## 210. Use of Mines, Bombs, and Shells for Demolition

a. General. Use of such charges is generally uneconomical, but may be necessary. Great care should be exercised, especially in the case of mines. "Dud" shells or bombs should never be used.
b. Mines. Table 220 shows the weights and explosive contents of certain American and foreign antitank mines or equivalent. British mines listed are obsolete but still in use. German mines listed are from World War II; considerable stocks exist in various European countries.
c. Explosive Content of General-Purpose Bombs. The explosive content of bombs is approximately half their total weight. When used for demolitions, they are most effective as cratering charges. Their
shape makes them inefficient for demolitions requiring close contact between the explosive and the material to be blown. Data are given in table 221.
d. Artillery Shells. Artillery shells are used for demolition only where a fragmentation effect is desired. Because of their low explosive content they are seldom used for other demolition purposes. The $105-\mathrm{mm}$. howitzer HE shell weighs 33 pounds, but contains only 5

Table 220. Weights and Explosive Contents of Mines

| Type | Weight of mine (pounds) | Weight of explosive (pounds) |
| :---: | :---: | :---: |
| UNITED STATES: |  |  |
| M-7 (limited standard) (metal) | 41/2 | 31/4 |
| M-6 (limited standard) (metal) | 20 | 12 |
|  | 30 | 21 |
| M-19 (standard) (plastic) | 28 | 21 |
| UNION OF SOVIET SOCIALIST REPUBLICS: |  |  |
|  | 11. 4 | 6. 1 |
|  | 11. 2 | 6. 1 |
| TM-39 (metal) | 11. 4 | 7. 9 |
| TM-41 (metal) | 11-12 | 8. 8 |
| TM-44 (metal) | 15. 4-17. 6 | 11 |
| TMD-B (wood) | 15-17 | 10. 3-12. 1 |
| YAM-5 (wood) | 13-15 | 11-12 |
| YAM-10 (wood) | 22-27 | 16-22 |
| TMB-2 (cardboard) | 15. 4 | 11 |
| LMG Rocket Mine (A1T roeket) | 22 | 7. 16 |
| Dog Mine (eanvas charge ease) | 29-30 | 26. 4 |
| (All above mines are "standard" items.) |  |  |
| Chinese Mine No. 8 (limited use) (metal) | 12 | 5 |
| Chinese Mine No. 4 (standard) (metal) | 16 | 12 |
| GREAT BRITAIN: |  |  |
| GS A/T Mark V (metal) | 8. 75 | 4. 5 |
| GS A/T Mark V HC (metal) | 8. 75 | 8. 25 |
| GS A/T Mark VC (metal) | 8. 75 | 4. 5 |
| FRANCE: |  |  |
| M-1936 (metal) | 14. 5 | 5. 75 |
| M-1935 (metal) | - 27 | 3. 25 |
| M-1947 (undetcctable) | 24. 3 | 13. 2 |
| M-1948 (plate eharge) | 27.5 | 16. 5 |
| M-1951 (probe proof) | 12.5-17. 5 | 11-16 |
| M-1951 (undctcetable) | 16-20 |  |
| GERMANY: |  |  |
| Tellermine 29 (metal) | 13 | 10 |
| Tellermine 35 \& 35 stecl (metal) | 19 | 11 |
| Tellermine 42 (metal) | 19 | 11 |
| Tcllcrmine 43 (metal)-------------------------1 | 18 | 12 |
| Topfmine A (bituminous eoal waste ease)------ | 21. 25 | 13 |
| Topfmine B \& C (bituminous coal wastc case)-- | 21. 25 | 13 |

Table 221. Weights and Explosive Contents of Mines

| Bomb | Total welght (pounds) | Explosive weight (pounds) |
| :---: | :---: | :---: |
| 100-pound GP, AN-M30_ | 115 | 57 |
| 250-pound GP, AN-M57 | 260 | 129 |
| 300 -pound GP, M31. | 280 | 144 |
| 500-pound GP, AN-M43 | 525 | 267 |
| 1,000-pound GP, AN-M44 | 990 | 558 |
| 2,000-pound GP, AN-M34 | 2, 100 | 1, 117 |

pounds of explosive. The $155-\mathrm{mm}$. howitzer HE shell contains but 15 pounds. Standard firing devices are adaptable only by using expedient methods for attachment to the shells.

## 211. Magazine Location

a. Accessibility, safety, dryness, and good drainage determine the magazine location. An isolated ravine is a good location. When single magazines are not isolated, or where magazines are built in groups, each magazine should be surrounded with breastworks or baffle walls to minimize damage to adjacent structures in case of an explosion, and to protect magazines from bomb and shell fragments.
b. The Ordnance Department has established quantity-distance tables, which furnish a correlation between the amount and kind of explosives in a magazine and the minimum distances of the magazine from various types of installation.
(1) Nature of explosive. Explosives and allied substances handled by the Ordnance Corps are divided into thirteen classes, numbered classes $1,2,2 \mathrm{a}, 3,4,5,6,7,8,9,10,11$, and 12.
(2) Distance categories. Six categories are considered:
(a) Inhabited building distance.
(b) Public railway distance.
(c) Public highway distance.
(d) Intraline distance, defined as the minimum distance between any two buildings within one operating line.
(e) Magazine distance, defined as the minimum distance between any two storage magazines.
(f) Missile distance, identified as inhabited building distance for ammunition in classes $3,4,5$, and 7 .
(3) Quantity-distance tables. For each class of explosives there is a quantity-distance table showing, for various amounts of stored explosive, what are the minimum distances of the several categories.
(4) Typical quantity-distance table. Table 222 is the quantitydistance table for class 2 explosives, a common category.

Class 2 includcs certain types of solid propellant (smokeless powder), chemical ammunition, military pyrotechnics, and some other items. The table applics for materials packed in approved storage containers, and/or cartridge cases; for smokeless powder in bulk, the minimum distances are higher. The table is in general typical of the various quantity-distance tables; but some classes of explosivesfor example, class 8 , which includes blasting caps, detonators, pcrcussion elements, and electric primers-require considerably higher minimum distances

Table 222. Quantity-Distance Table for Class 2 Materials
(Materials packed in approved storage containers and/or cartridge cases)

| Quantity |  | Distance in feet |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Pounds (over) | $\underset{\text { (not over) }}{\text { Pounds }}$ | Inhabited bullding distance | $\begin{gathered} \text { Public } \\ \text { railway } \\ \text {-distance } \end{gathered}$ | Publle <br> highway <br> -distance | Magazine and intraline distance |
| 100. | 1, 000 | 75 | 75 | 75 | 50 |
| 1,000. | 5, 000 | 115 | 115 | 115 | 75 |
| 5,000 | 10,000 | 150 | 150 | 150 | 100 |
| 10,000 | 20, 000 | 190 | 190 | 190 | 125 |
| 20,000 | 30, 000 | 215 | 215 | 215 | 145 |
| 30,000. | 40, 000 | 235 | 235 | 235 | 155 |
| 40,000 | 50, 000 | 250 | 250 | 250 | 165 |
| 50,000 | 60, 000 | 260 | 260 | 260 | 175 |
| 60,000 | 70, 000 | 270 | 270 | 270 | 185 |
| 70,000 | 80, 000 | 280 | 280 | 280 | 190 |
| 80,000 | 90, 000 | 295 | 295 | 295 | 195 |
| 90,000 | 100, 000 | 300 | 300 | 300 | 200 |
| 100,000 | 200, 000 | 375 | 375 | 375 | 250 |
| 200,000 | 300, 000 | 450 | 450 | 450 | 300 |
| 300,000 | 400, 000 | 525 | 525 | 525 | 350 |
| 400,000 . . . . - | 500, 000 | 600 | 600 | 600 | 400 |

## CHAPTER 11

## MISCELLANEOUS DATA

## Section I. MATHEMATICAL DATA

## 212. Lengths, Areas, and Volumes

a. Legend.
$A=$ area
$a=$ altitude
$b=$ length of base
$c=$ hypotenuse
$C=$ circumference
$r=$ radius
$D=$ diameter
$\pi=3.1416$
$l=$ length of arc
$k=$ length of chord
$V=$ volume
b. Formulas.
(1) Any triangle. $A=1 / 2 a b$
(2) Right triangle. $a=\sqrt{c^{2}-b^{2}}$

$$
\begin{aligned}
& b=\sqrt{c^{2}-a^{2}} \\
& c=\sqrt{a^{2}+b^{2}}
\end{aligned}
$$

(3) Circle. $A=\pi r^{2}$

$$
A=0.7854 \mathrm{D}^{2} \quad C=\pi D
$$

(4) Segment of circle.

$$
\begin{aligned}
A & =1 / 2[r(l-k)+a k] \\
l & =\frac{\pi r}{180}(\text { angle in degrees }) \\
k & =2 \sqrt{2 a r-a^{2}}
\end{aligned}
$$

(5) Sector of circle.

$$
A=\frac{r l}{2}=\frac{\pi r^{2}}{360} \cdot(\text { angle in degrees })
$$

(6) Regular polygons. The area of any regular polygon (all sides equal; all angles equal) is equal to the product of the square of the length of one side and the factors shown in table 223. Example: Area of regular octagon having 6 -inch sides is $6 \times 6 \times 4.828$ or 173.81 square inches.
(7) Rectangle and parallelogram.

$$
A=a b
$$

Table 223. Polygon Factors .

| Number of sides | Factor | Number of sides | Factor |
| :---: | :---: | :---: | :---: |
| 3. | 0. 433 | 8. | 4. 828 |
| 4. | 1. 000 | 9 | 6. 182 |
| 5. | 1. 720 | 10 | 7. 694 |
| 6 | 2. 598 | 11 | 9. 366 |
| 7. | 3. 634 | 12 | 11. 196 |

(8) Trapezoid.

$$
A=1 / 2 a\left(b_{1}+b_{2}\right)
$$

(9) Irregular figures. Measure widths at offsets regularly spaced along any straight line, and apply one of the following:
(a) Trapezoidal rule. $A=1 / 2$ interval between offsets X (sum of two end widths plus twice the sum of the intermediate widths).
(b) Simpson's rule. (Assumes lateral boundaries are parabolic curves.) $A=1 / 3$ interval between offsets X [sum of two end widths plus twice the sum of the odd widths except first and last (3d, 5th, 7 th, etc.) plus 4 times the sum of the even widths (2d, 4th, 6th, etc.)]. (Note: The rule requires an odd number of widths. If there is an even number, compute separately the area of a trapezoid at one end.)
(10) Cube.

$$
V=b^{3}
$$

(11) Rectangular parallelepiped.

$$
V=a b_{1} b_{2}
$$

(12) Prism or cylinder.

$$
V=a X \text { (area of base) }
$$

(13) Pyramid or cone.

$$
V=1 / 3 a X \text { (area of base) }
$$

(14) Sphere.

$$
\begin{aligned}
& V=4 / 3 \pi r^{3}=\frac{\pi D^{3}}{6} \\
& A=4 \pi r^{2}
\end{aligned}
$$

(15) Prismoidal section.
$V=1 / 6$ length $X$ (sum of end areas plus 4 times midsection area)

## 213. Numerical Constants Containing $\pi$

Table 224. Numerical Constants Containing $\pi$

| $\pi=3.1415926536$ |  | $\log _{10} \pi=0.497 .1498727$ |  | $10_{\mathrm{ge}} \pi=1.1447298858$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | No. | Logarithm |  | No. | Logarithm |
| $\pi$ | 3. 1415927 | 0. 4971499 | $\pi^{2}$ | 9. 8696044 | 0.9942997 |
| $2 \pi$ | 6. 2831853 | 0. 7981799 | $2 \pi^{2}$ | 19.7392 088 | 1. 2953297 |
| $3 \pi$ | 9. 4247780 | 0. 9742711 | $4 \pi^{2}$ | 39.4784 176 | 1. 5963597 |
| $4 \pi$ | 12. 5663706 | 1. 0992099 | $1 / \pi^{2}$ | 0. 1013212 | 9. 0057 003-10 |
| $8 \pi$ | 25. 1327412 | 1. 4002399 | $1 /\left(2 \pi^{2}\right)$ | 0. 0506606 | 8. $7046703-10$ |
| $\pi / 2$ | 1. 5707963 | 0. 1961199 | $1 /\left(4 \pi^{2}\right)$ | 0. 0253303 | 8. 4036 403-10 |
| $\pi / 3$ | 1. 0471976 | 0. 0200286 | $\sqrt{\pi}$ | 1. 7724539 | 0. 2485749 |
| $\pi / 4$ | 0.7853.982 | 9. $8950899-10$ | $\sqrt{\pi / 4}$ or | 0. 8862269 | 9. $9475449-10$ |
| $\pi / 6$ | 0. 5235988 | 9. 7189 986-10 | $\sqrt{\pi / 2}$ |  |  |
| $\pi / 8$ | 0. 3926991 | 9. $5940 \quad 599-10$ | $\sqrt{\pi / 4}$ | 0.4431. 135 | 9. $6465149-10$ |
| $2 \pi / 3$ | 2. 0943951 | 0. 3210586 | $\sqrt{\pi 1 / 2}$ | 1. 2533141 | 0. 0980599 |
| $4 \pi / 3$ | 4. 1887902 | 0. 6220886 | $\sqrt{2 / \pi}$ | 0. 7978.846 | 9. 9019 401-10 |
| $1 / \pi$ | 0.3183 099 | 9.5028 501-10 | $\pi^{3}$ | 31. 0062767 | 1. 4914496 |
| 2/ $/$ | 0. 6366198 | 9. $8038801-10$ | $\sqrt[3]{\pi}$ | 1. 4645919 | 0. 1657166 |
| 4/ | 1. 2732395 | 0. 1049101 | $1 / \sqrt[3]{\pi}$ | 0. 6827841 | 9. $8342834-10$ |
| $1 /(2 \pi)$ | 0. 1591549 | 9. 2018 201-10 | $\sqrt[3]{\pi / 2}$ | 2. 1450294 | 0. 3314332 |
| $1 /(4 \pi)$ | 0. 0795775 | 8. $9007901-10$ | $1 / \sqrt{\pi}$ | 0. 5641896 | 9. 7514 251-10 |
| $1 /(6 \pi)$ | 0.0530516 | 8. $7246989-10$ | $2 / \sqrt{\pi}$ or | 1. 1283792 | 0. 0524551 |
| $1 /(8 \pi)$ | 0. 0397887 | 8. 5997 601-10 | $\sqrt{4 / \pi}$ |  |  |
| $\pi / 90$ | 0. 0349066 | 8. 5429 075-10 |  |  |  |
| $\pi / 180$ | 0. 0261799 | 8. $4179679-10$ |  |  |  |
| $\pi / 270$ | 0. 0174533 | 8. $2418776-10$ |  |  |  |
| $\pi / 360$ | 0. 0087266 | 7. $9408451-10$ |  |  |  |
|  |  |  |  |  |  |

## 214. Algebraic Formulas

a. Factors and Expansions.
$(a+b)^{2}=a^{2} \pm 2 a b+b^{2}$
$(a+b)^{3}=a^{3} \pm 3 a^{2} b+3 a b^{2}+b^{3}$
$(a+b)^{4}=a^{4} \pm 4 a^{3} b+6 a^{2} b^{2} \pm 4 a b^{3}+b^{4}$
$a^{2}-b^{2}=(a-b)(a+b)$
$a^{2}+b^{2}=(a+b \sqrt{-1})(a-b \sqrt{-1})$
$a^{3}-b^{3}=(a-b)\left(a^{2}+a b+b^{2}\right)$
$a^{3}+b^{3}=(a+b)\left(a^{2}-a b+b^{2}\right)$
$a^{4}+b^{4}=\left(a^{2}+a b \sqrt{2}+b^{2}\right)\left(a^{2}-a b \sqrt{2}+b^{2}\right)$
$a^{n}-b^{n}=(a-b)\left(a^{n-1}+a^{n-2} b+\ldots+b^{n-1}\right)$, for odd values of $n$.
$a^{n}-b^{n}=(a+b)\left(a^{n-1}-a^{n-2} b+\ldots-b^{n-1}\right)$, for even values of $n$.
$b$. Binomial Theorem. The expansion of $(a+b)^{n}$, where $n$ is a positive integer is
$(a+b)^{n}=a^{n}+n a^{n-1} b+\frac{n(n-1)}{2^{\prime}} a^{n-2} b^{2}$

$$
\begin{aligned}
& +\frac{n(n-1)(n-2)}{3^{\prime}} a^{n-3} b^{3}+\ldots \\
& +\frac{n(n-1)(n-2) \ldots(n-r+2)}{(r-1)^{\prime}} a^{n-4+1} b^{r-1}+\ldots+b^{n}
\end{aligned}
$$

c. Quadratic Equation. The roots of any quadratic equation when reduced to the form $a x^{2}+b x+c=O$ are

$$
x=\frac{-b \pm \sqrt{b^{2}-4 a c}}{2 a}
$$

If ( $b^{2}-4 a c$ ) is positive, the roots are real and unequal.
If ( $b^{2}-\dot{4} a c$ ) is zero, the roots are real and equal.
If $\left(b^{2}-4 a c\right)$ is negative, the roots are imaginary and unequal.
If ( $b^{2}-4 a c$ ) is a perfect square, the roots are rational and unequal.

- d. Powers and Roots.

$$
\begin{array}{lll}
a^{x} \cdot a^{y}=a^{(x+y)} & a^{0}=l(\text { if } a=0) & (a b)^{x}=a^{x} b^{x} \\
\frac{a^{x}}{a^{y}}=a^{(x-y)} & a^{-x}=\frac{l}{a^{x}} & \left(\frac{a}{b}\right)^{x}=\frac{a^{x}}{b^{x}} \\
\left(a^{x}\right)^{y}=a^{x y} & a^{\frac{l}{x}}=x \sqrt{a} & x \sqrt{a b}=x \sqrt{a} x \sqrt{b} \\
x \sqrt{y \sqrt{a}}=x y \sqrt{a} & a^{\frac{x}{y}}=y \sqrt{a^{x}} & x \sqrt{\frac{a}{b}}=\frac{x \sqrt{a}}{x \sqrt{b}}
\end{array}
$$

e. Proportion.

If $\frac{a}{b}=\frac{c}{d}$
then $\frac{a+b}{b}=\frac{c+d}{d}, \frac{a-b}{b}=\frac{c-d}{d}, \frac{a-b}{a+b}=\frac{c-d}{c+d}$

## f. Logarithms.

If $a^{0}=x$,
then $\log _{a} x=b$, by definition.
For change of base, $\log _{a} x=\frac{\log _{c} x}{\log _{\cdot} a}$
To any base, $\quad \log M N=\log M+\log N$

$$
\log M^{A}=A \log M
$$

$$
\log \frac{M}{N}=\log M N^{-1}=\log M-\log N
$$

$$
\log n \sqrt{M}=\log M^{\frac{1}{n}}=\frac{l}{n} \log M
$$

g. Sums of Numbers.

The sum of the first $n$ numbers,

$$
\sum(n)=1+2+3+4+5+\ldots+n=\frac{n(n+1)}{2}
$$

The sum of the squares of the first $n$ numbers,

$$
\sum\left(n^{2}\right)=1^{2}+2^{2}+3^{3}+4^{2}+5^{2}+\ldots+n^{2}=\frac{n(n+1)(2 n+1)}{6}
$$

The sum of the cubes of the first $n$ numbers,

$$
\sum\left(n^{3}\right)=1^{3}+2^{3}+3^{3}+4^{3}+5^{3}+\ldots+n^{3}=\frac{n^{2}(n+1)^{2}}{4}
$$

h. Arithmetical Progression. If $a$ is the first term; $l$, the last term; $d$, the common difference; $n$, the number of terms; and $s$, the sum of $n$ terms, then

$$
1=a+(n-1) d \quad s=\frac{n}{2}(a+1) \quad s=\frac{n}{2}[2 a+(n-1) d]
$$

$i$. Geometrical Progression. If $a$ is the first term; $l$, the last term; $r$, the common ratio; $n$, the number of terms; and $s$, the sum of $n$ terms, then
$l=a r^{n-1} \quad s=a \frac{\left(l-r^{n}\right)}{l-r}$.
$s=a \frac{\left(r^{n-1}\right)}{r-l} \quad s=\frac{l r-a}{r-l}$
If $n$ becomes infinite and $r$ less than unity: $-s=\frac{a}{l-r}$
j. Factorials. The symbol $n$ '., call " $n$ factorial", represents the product of the first $n$ positive integers.
$n^{\prime} .=1.2 .3$. . $n$.
$O^{\prime}=1$, by definition.
$n^{\prime},=e^{-n} n^{n} \sqrt{2 \pi n}$, approximately.
$k$. Permutations. If $P$ denotes the number of permutations of $n$ things taken $r$ at a time, then
$P=n(n-l)(n-2) \ldots(n-r+l)$
$l$. Combinations. If $C$ denotes the number of combinations of $n$ things taken $r$ at a time, then
$C=\frac{n(n-1)(n-2) \ldots(n-r+1)}{r^{\prime} .}$
$C=\frac{n^{\prime} .}{r^{\prime} \cdot(n-r)^{\prime}}$.

## Section II. PHYSICAL DATA

## 215. Equivalents of Measure

Equivalent lengths, areas, cubes, weights, pressures, densities, velocities, work measurements, and U.S. weight equivalents are given in tables 225-233. Conversion scales for temperatures, lengths, and gallons are shown in figure 109.


Figure 109. Conversion scales.

Table 225. Lengths

| $\begin{gathered} \text { Meters,* } \\ \text { m } \end{gathered}$ | Inches, in. | Feet,$\mathrm{ft} .$ | Yard, yd. | Rods, | $\begin{gathered} \text { Cbains, } \\ \text { ch. } \end{gathered}$ | Miles, U.S. |  | $\underset{\mathrm{km}}{\text { Kilometers, }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | Statute | Nautical |  |
| 1. | 39.37 | 3.28083 | 1.09361 | 0.19884 | 0.04971 | $0.0{ }_{6}^{3} 6214$ | $0.0{ }_{0}^{3} 5396$ | 0.001 |
| . 02540 | 1 | . 08333 | . 02778 | ${ }_{.0}^{2} 5051$ | ${ }_{.0}^{2} 1263$ | ${ }_{0}^{4} 1578$ | ${ }_{.0}^{4} 1371$ | ${ }_{.0}^{4} 2540$ - |
| . 30480 | 12 | 1 | . 33333 | . 06061 | . 01515 | ${ }_{.0}^{3} 1894$ | ${ }_{.0}^{3} 1645$ | ${ }_{-0}^{3} 3048$ |
| . 91440 | 36 | 3 | 1 | . 18182 | . 04545 | ${ }_{.0}^{3} 5682$ | ${ }_{-0}{ }^{3} 4934$ | ${ }_{.0}^{3} 9144$ |
| 5.02921 | 198 | 16.5 | 5.5 | 1 | . 25 | ${ }_{.0}^{2} 3125$ | ${ }_{-0}^{2} 2714$ | ${ }_{.0}^{2} 5029$ |
| 20.1168 | 792 | 66 | 22 | 4 | 1 | . 01250 | . 01085 | . 02012 |
| 1609.35 | 63360 | 5280 | 1760 | 320 | 80 | 1 | . 86839 | 1.60935 |
| 1853.25 | 72962.5 | 6080.20 | 2026.73 | 368.497 | 92.1243 | 1.15155 | 1 | 1.85325 |
| 1000 | 39370 | 3280.83 | 1093.61 | 198.838 | 49.7096 | . 62137 | . 53959 | 1 |

* 1 meter $(\mathrm{m})=10$ decimeters $(\mathrm{dm})=100$ centimeters $(\mathrm{cm})=1,000$ millimeters (mm).

Example: 1 meter $=0 .{ }_{0}^{3} 6214=0.0006214$ statute miles.
Table 226. Areas

| Sq. meters, sq. m | Sq. inches, sq. in. | Sq. feet, sq. ft. | Sq. yards, sq. yd. | Sq. rods, sq. r. | $\underset{\text { Acres, }}{\text { A }}$ | $\begin{aligned} & \text { Hectares, } \\ & \text { ha. } \end{aligned}$ | Sq. miles, Statute | Sq. kilometers, <br> sq. km |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | 1550.00 | 10.7639 | 1.19599 | 0.03954 | . $0 .{ }_{0}^{3} 2471$ | 0.0001 | 0.63861 | $0 .{ }_{0}^{5} 1$ |
| ${ }^{1}{ }_{0}^{3} 6452$ | 1550.00 | ${ }_{.0}^{2} 6944$ | ${ }^{.} .87716$ | ${ }_{.0}^{\text {e }} 25551$ | ${ }_{.0}^{6} 1594$ | . 76452 | ${ }_{.0}^{9} 2491$ | ${ }_{.0}^{9} 6452$ |
| .069290 | 144 | 1 | . 11111 | ${ }_{.}^{2} 3673$ | ${ }_{-0}^{4} 2296$ | ${ }^{5} 99290$ | ${ }_{.}^{7} 3587$ | ${ }_{.0}^{7} 9290$ |
| . 83613 | 1296 | 9 | 1 | . 03306 | ${ }_{.0}^{3} 2066$ | ${ }_{.0}^{4} 8361$ | ${ }_{.0}^{6} 3228$ | ${ }_{0}^{6} 8361$ |
| 25.2930 | 39204 | 272.25 | 30.25 | 1 | . 00625 | ${ }_{.0}^{3} 2529$ | ${ }_{.0}^{5} 9766$ | ${ }_{0}^{4} 2529$ |
| 4046.87 | 6272640 | 43560 | 4840 | 160 | 1 | . 40469 | ${ }_{-2}^{2} 1563$ | ${ }_{.0}^{2} 4047$ |
| 10000 | 15499969 | 107639 | 11959.9 | 395.366 | 2.47104 | 1 | ${ }_{.0}^{2} 3861$ | . 01 |
| 2589999 |  | 27878400 | 3097600 | 102400 | 640 | 259.000 |  | 2.59000 |
| 1000000 |  | 10763867 | 1195985 | 39536.6 | 247.104 | 100 | . 38610 | 1. |

Table 287. Cubic Mcasures ${ }^{1}$

| Cuble Declmeters, dmo or Lters | Cuble Inches, cu. in. | Cublc Feet, cu. ft. | Cuble Yards, cu. yd. | U.S. Quarts |  | U.S. Gullons |  | $\begin{aligned} & \text { U.S. Bushels, } \\ & \text { bu. } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Llquld, 1. qt. | Dry d. $4 t$. | Llquid, I. gat. | Dry, d. gal. |  |
| 1 | 61.0234 | 0.03531 | 0.01308 | 1.05668 | 0.90808 |  |  |  |
| . 01639 | 1 | ${ }^{.}{ }_{0} 5787$ | . .0 .0 .0143 | 1.05668 .01732 | 0.90808 .01488 | $\begin{array}{r}0.26417 \\ .04329 \\ \hline .0\end{array}$ | 0.22702 <br> .3 <br> 2720 | 0.02838 24650 |
| 28.3170 | 1728 | 1 | . 03704 | 29.9221 | 25.7140 | : $\begin{array}{r}\text {.0.04329 } \\ \\ \hline\end{array}$ | .30820 6.42851 | -04650 |
| 764.559 | 46656 |  | ${ }^{1}$ | 807.896 | 694.279 | 201.974 | 6.42851 173.570 | . 80356 |
| . 94636 | 57.75 | . 03342 | ${ }_{.}^{2} 1238$ | 1 | .85937 | 201.974 .25 | 173.570 . <br> 21484 | 21.6962 |
| 1.10123 | 67.2006 | . 03889 | ${ }_{.}^{2} 1440$ | 1.16365 | $1^{.85937}$ | . 259091 | .21484 .25 | . 02686 |
| 3.78543 | 231 | . 13368 | ${ }_{-0}^{2} 4951$ | 4 | 3.43747 | .$^{.29091}$ | . 855937 | . 03125 |
| 4.40492 | 268.803 | . 15556 | ${ }_{.0}^{2} 5761$ | 4.65460 | 4 | 1.16365 | $1^{.85937}$ | .10742 .125 |
| 35.2393 | 2150.42 | 1.24446 | . 04609 | 37.2368 | 32 | 9.30920 | 8 | $1^{.125}$ |

1 Sec alsó par. 82.
U.S. dry measure: 1 bushel $=4$ pecks $=8$ galions $=32$. quarts $=64$ plnts.
U.S. llquid measure: 1 gallon=4 quarts=8 plnts=32 gills=128 fluid ouncus. 1 U.S. gallon=0.83268 Imperial gallon.

Table 228. Weights

| Kilograms, $\mathbf{k g}$ | Grains, gr. | Ounces |  | Pounds |  | Tons |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Troy, oz. t. | A volr., oz, av. | Troy, li. t. | Avolr., lb. av. | Net (short), 2000 lbs. | Gross, (long), 2240 lbs. | Metric 1000 kg |
| 1 | 15432.4 | 32.1507 | 35.2740 | 2.67923 | 2.20462 | 0.021102 | $0 .{ }_{0}^{3} 9842$ | 0.001 |
| ${ }_{.0}^{4} 6480$ | 1 | .$_{0}^{2} 2083$ | ${ }_{.0}^{3} 2286$ | ${ }_{.0}^{3} 1736$ | ${ }_{.0}^{3} 1429$ | ${ }_{.}^{7} 7143$ | ${ }_{.0}^{7} 6378$ | . 76480 |
| . 03110 | 480 | 1 | 1.09714 | . 08333 | . 06857 | ${ }_{.}^{4} 3429$ | ${ }^{4} 3061$ | ${ }_{0}^{4} 3110$ |
| . 02385 | 437.5 | . 91146 |  | . 07595 | . 06250 | ${ }_{-0}^{4} 3125$ | ${ }_{.0}^{4} 2790$ | ${ }_{.0}^{4} 2835$ |
| . 37324 | 5760 | 12 | 13.1657 | 1 | . 82286 | ${ }_{.0}^{3} 4114$ | ${ }_{.0}{ }_{0} 3674$ | ${ }_{-} 33732$ |
| . 45359 | 7000 | 14.5833 | 16 | 1.21528 | 1 | . 00050 | ${ }_{.0}^{3} 4464$ | ${ }^{.} \mathbf{0} 4536$ |
| 907.185 | 14000000 | 29166.7 | 32000 | 2430.56 | 2000 | 1 | . 89286 | . 90719 |
| 1016.05 | 15680000 | 32666.7 | 35840 | 2722.22 | 2240 | 1.12 | 1 | 1.01605 |
| 1000 | 15432356 | 32150.7 | 35274.0 | 2679.23 | 2204.62 | 1.10231 | . 98421 | 1 |

[^49]Table 229. Pressures

| Kllograms per sq. centlmetcr, $\mathrm{kg} / \mathrm{cm}^{2}$ | Pounds per sq. incb, lb./iu. ${ }^{2}$ | Pounds jer sq. foot, lb./ft. ${ }^{2}$ | Net tons, (2000 lbs.), per sq. foot | Atmospliercs, Standard, 760 um | Columns of mercury, (Hg), 13.59593 Sp . G. |  | Columis of water, max. denslty $4^{\circ} \mathrm{C}$. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Millmeters | Inches | Meters | Fect |
| . 1 | 14.2234 | 2048.17 | 1.02408 | 0.96778 | 735.514 | 28.9572 | 10 | 32.8083 |
| . 07031 | 1 | 144 | . 07200 | . 06804 | 51.7116 | 2.03588 | . 70307 | 2.30665 |
| ${ }_{.0}^{3} 4882$ | ${ }_{.0}^{2} 6944$ | 1 | . 00050 | ${ }_{.0}^{3} 4725$ | . 35911 | . 01414 | ${ }_{.0}^{2} 4882$ | . 01602 |
| . 97648 | 13.8889 | 2000 | 1 | . 94502 | 718.216 | 28.2762 | 9.76482 | 32.0367 |
| 1.03329 | 14.6969 | 2116.35 | 1.05818 | 1 | 760 | 29.9212 | 10.3329 | 33.9006 |
| ${ }_{.}^{2} 1360$ | . 01934 | 2.78468 | $1 .{ }_{0}^{2} 1392$ | ${ }^{2} 1316$ | 1 | . 03937 | . 01360 | . 04461 |
| . 03453 | . 49119 | 70.7310 | . 03537 | . 03342 | 25.4001 | 1 | . 34534 | 1.13299 |
| . 10 | 1.42234 | 204.817 | . 10241 | . 09678 | 73.5514 | 2.89572 | 1 | 3.28083 |
| . 03048 | . 43353 | 62.4283 | . 03121 | . 02950 | 22.4185 | . 88262 | . 30480 | 1 |

Tablc 230. Densilies

| $\underset{\substack{\text { Grams } \\ \text { percu. centlmeter } \\ \mathrm{g} / \mathrm{cm}}}{ }$ | $\begin{aligned} & \text { Pounds } \\ & \text { per cu. Ineh } \\ & \text { lb./In. } \end{aligned}$ | Pounds jer cu. foot lb./ft | Pounds per ent yard lb. $\mathrm{yyd} \mathrm{B}^{3}$ | Kllograms per cu. meter $\mathrm{kg} / \mathrm{m}{ }^{2}$ | $\begin{aligned} & \text { Pounds } \\ & \text { per bushel, } \\ & \text { U.S. } \end{aligned}$ | $\begin{aligned} & \text { Pounds } \\ & \text { per gallon, dry } \\ & \text { U.S. } \end{aligned}$ | $\begin{gathered} \text { Pounuls } \\ \text { per galloullitutu, } \\ \text { U.S. } \end{gathered}$ | $\begin{gathered} \text { Kllograins } \\ \text { per hectollter } \\ \mathrm{kg} / \mathrm{hl} \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | 0.03613 | 62.4283 | 1685.56 | 1000 | 77.6893 | 9.71116 | 8.34545 | 100 |
| 27.6797 | 1 | 1728 | 46656 | 27679.7 | 2150.42 | 268.803 | 231 | 2767.97 |
| . 01602 | ${ }_{.0}^{3} 5787$ | 1 | 27 | 16.0184 | 1.24446 | . 15556 | . 13368 | 1.60184 |
| ${ }_{.0}^{3} 5933$ | ${ }_{.}^{4} 2143$ | . 03704 | 1 | . 59327 | . 04609 | ${ }^{.} 25762$ | ${ }_{.}^{2} 4951$ | . 05933 |
| . 001 | ${ }_{.}^{4} 3613$ | . 06243 | 1.68556 | 1 | . 07769 | .$^{2} 9711$ | .$_{0}^{2} 8345$ | . 10 |
| . 01287 | ${ }_{.0}^{3} 4650$ | . 80356 | 21.6962 | 12.8718 | 1 | . 125 | . 10742 | 1.28718 |
| . 10297 | ${ }_{.0}^{2} 3720$ | 6.42851 | 173.570 | 102.974 | 8 | 1 | . 85937 | 10. 2974 |
| . 11983 | ${ }_{.0}^{2} 4329$ | 7.48052 | 201.974 | 119.826 | 9.30920 | 1.16365 | 1 | 11.9826 |
| . 01 | ${ }_{.0}^{33} 3613$ | . 62428 | 16.8557 | 10 | . 77689 | . 09711 | . 08345 | 1 |

Table 291. Velocities

| Meters per second (m./sec.) | Feet per second (ft./sce.) | $\begin{aligned} & \text { Miles per hour } \\ & \text { (m.p.h.) } \end{aligned}$ | Nautical miles per hour (knots) (U.S.) | Kilometers per hour ( $\mathrm{km} / \mathrm{hr}$.) |
| :---: | :---: | :---: | :---: | :---: |
| 1 | 3. 28083 | - 2.23693 | 1. 94254 | 3.6 |
| . 30480 | 1 | . 68182 | 59209 | 1. 09728 |
| . 44704 | 1. 46667 | 1 | . 86839 | 1. 60935 |
| . 51479 | 1. 68894 | 1. 15155 | 1 | 1. 85325 |
| . 27778 | . 91134 | . 62137 | . 53959 | 1 |

Table 232. Work Measurements

| Kilogram-meters per second, $\mathrm{kg}-\mathrm{m} / \mathrm{sec}$. | Foot-pounds per second, ft.-1bs./sec. | Horsepower |  | $\begin{gathered} \text { Poncelet, } 100 \\ \mathrm{~kg}-\mathrm{m} / \mathrm{sec} . \end{gathered}$ | Kilowatt, kw. | Watts, $10 \mathrm{ergs} / \mathrm{sec}$. | Thermal units per Sec. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\begin{aligned} & \text { U.S., } 550 \\ & \text { ft.-ibs./sec. } \end{aligned}$ | Metric, 75 $\mathrm{kg}-\mathrm{m} / \mathrm{sec}$. |  |  |  | $\begin{aligned} & \text { B.T.U., } \\ & \text { B.T./sec. } \end{aligned}$ | Calorle, kg-cal/sec. |
| 1 | 7.23300 | 0.01315 | 0.01333 | 0.01 | 0.09806 | 9.80597 | 0.02996 | $0 .{ }_{0}^{2} 2342$ |
| . 13826 | 1 | ${ }_{.0}^{2} 1818$ | ${ }_{.0}^{2} 1843$ | ${ }_{.0}^{2} 1383$ | ${ }_{.}^{2} 1356$ | 1.35573 | ${ }_{.}^{2} 1285$ | ${ }_{.}{ }_{0} 3237$ |
| 76.0404 | 550 | 1 | 1.01387 | . 76040 | . 74565 | 745.650 | . 70865 | . 17812 |
| 75 | 542.475 | . 98632 | 1 | . 75 | . 73545 | 735.448 | . 69718 | . 17569 |
| 100 | 723.300 | 1.31509 | 1.33333 | 1 | . 98060 | 980.597 | . 92957 | . 23425 |
| 101.979 | 737.612 | 1.34111 | 1.35972 | 1.01979 | 1 | 1000 | .94796 | . 23888 |
| . 10198 | . 73761 | ${ }_{.0}^{2} 1341$ | ${ }_{.0}^{2} 1360$ | ${ }_{.}^{2} 1020$ | . 001 | 1 | ${ }_{-0}^{3} 9480$ | ${ }_{.0}^{3} 2389$ |
| 107.577 | 778.104 | 1.41474 | 1.43436 | 1.07577 | 1.05490 | 1054.90 | 1 | . 25200 |
| 426.900 | 3087.77 | 5.61412 | 5.69200 | 4.26900 | 4.18617 | 4186.17 | 3.96832 | 1 |

Table 293. United States Weight Equivalents

| A voirdupois pounds | Kilograms | Short tons | Long tons |
| :---: | :---: | :---: | :---: |
| 1. | 0. 45359 | 0. 0005 | 0. 00044643 |
| 2 | . 90718 | . 0010 | . 00089286 |
| 3 | 1. 36078 | . 0015 | . 00133929 |
| 4 | 1. 81437 | . 0020 | . 001.78571 |
| 5 | 2. 26796 | . 0025 | . 00223214 |
| 6 | 2. 72155 | . 0030 | . 00267857 |
| 7 | 3. 17515 | . 0035 | .00312500 |
| 8 | 3. 62874 | . 0040 | .00357143 |
| 9. | 4. 08233 | . 0045 | . 004.017 .86 |
| 2. 20462 | 1 | .00110231 | . 000.984 21 |
| 4.40924 | 2 | . 00220462 | . 001:968 41 |
| 6.61387 | 3 | . 00330693 | . 00295262 |
| 8.81849 | 4 | . 00440924 | . 00393683 |
| 11.02311 | 5 | . 00551156 | . 00492103 |
| 13.22773 | 6 | . 00661387 | . 00590524 |
| 15.43236 | 7 | . 00771618 | . 00688944 |
| 17.63698 | 8 | . 00881849 | . 00787365 |
| 19.84160 | 9 | . 00992080 | . 00885786 |

Table 233. United States Weight Equivalents-Continued

| A voirdupois pounds | Kilograms | Short tons | Long tons |
| :---: | :---: | :---: | :---: |
|  |  |  |  |
| 2000 | 907. 18 | 1 | $0 . .89286$ |
| 4000 | 1814. 37 | 2 | 1. 785.71 |
| 6000 | 2721. 55 | 3 | 2. 67857 |
| 8000 | 3628. 74 | 4 | 3. 57143 |
| 10000 | 4535. 92 | 5 | 4. 46429 |
| 12000 | 5443: 11 | 6 | 5. 35714 |
| 14000 | 6350. 29 | 7 | 6. 25000 |
| 16000 | 7257. 48 | 8 | 7. 14286 |
| 18000 | 8164. 66 | 9 | 8. 03571 |
| 2240 | 1016. 05 | 1. 12 | 1 |
| 4480. | 2032. 09 | 2. 24 | 2 |
| 6720 | 3048. 14 | 3. 36 | 3 |
| 8960 | 4064. 19 | 4. 48 | 4 |
| 11200 | 5080. 24 | 5. 60 | 5 |
| 13440 | 6096. 28 | 6. 72 | 6 |
| 15680 | 7112. 32 | 7. 84 | 7 |
| 17920 | 8128. 38 | 8. 96 | 8 |
| 20160 | 9144. 42 | 10. 08 | 9 |

## 216. Inches to Decimals of a Foot

Table 234. Inches to Decimals of a Foot

|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0 | 0 | 0.0833 | 0. 1667 | 0.2500 | 0. 3333 | 0. 4167 | 0. 5000 | 0. 5833 | 0.6667 | 0. 7500 . | 0. 8333 | 0. 9167 |
| $1 / 10$ | . 0052 | . 0885 | . 1719 | . 2552 | . 3385 | . 4219 | . 5052 | 5885 | 6719 | . 7552 | 8385 | . 9219 |
| 1/8 | . 0104 | 0938 | . 1771 | . 2604 | . 3438 | . 4271 | . 5104 | 5938 | . 6771 | . 7604 | 8438 | 9271 |
| 3/16 | . 0156 | . 0990 | . 1823 | . 2656 | . 3490 | . 4323 | . 5156 | 5990 | . 6823 | 7656 | 8490 | 9323 |
| 1/4. | . 0208 | . 1042 | . 1875 | . 2708 | . 3542 | . 4375 | . 5208 | . 6042 | . 6875 | . 7708 | 8542 | . 9375 |
| 5/10 | . 0260 | . 1094 | . 1927 | 2760 | . 3594 | . 4427 | . 5260 | . 6094 | . 6927 | . 7760 | 8594 | 9427 |
| 3/8 | . 0313 | . 1146 | . 1979 | . 2813 | . 3646 | . 4479 | . 5313 | . 6146 | . 6979 | . 7813 | . 8646 | 9479 |
| 7/16 | . 0365 | . 1198 | . 2031 | . 2865 | . 3698 | . 4531 | 5365 | . 6198 | . 7031 | . 7865 | . 8698 | . 9531 |
| 1/2 | . 0417 | 1250 | . 2083 | . 2917 | . 3750 | . 4583 | . 5417 | . 6250 | . 7083 | 7917 | . 8750 | . 9583 |
| 910 | . 0469 | -. 1302 | . 2135 | . 2969 | . 3802 | . 4635 | 5469 | . 6302 | . 7135 | . 7969 | . 8802 | . 9635 |
| 5/8 | . 0521 | 1354 | . 2188 | . 3021 | . 3854 | . 4688 | . 5521 | . 6354 | 7188 | . 8021 | . 8854 | . 9688 |
| 11/16 | . 0573 | . 1406 | . 2240 | . 3073 | . 3906 | . 4740 | . 5573 | . 6406 | . 7240 | . 8073 | . 8906 | 9740 |
| $3 / 4$ | . 0625 | . 1458 | . 2292 | . 3125 | . 3958 | . 4792 | . 5625 | . 6458 | . 7292 | . 8125 | . 8958 | . 9792 |
| 13/16 | . 0677 | 1510 | -. 2344 | . 3177 | . 4010 | . 4844 | . 5677 | . 6510 | . 7344 | . 8177 | . 9010 | . 9844 |
| 7/8 | . 0729 | . 1563 | . 2396 | . 3229 | . 4063 | . 4896 | . 5729 | . 6563 | . 7396 | . 8229 | . 9063 | . 9896 |
| 15/10- | . 0781 | . 1615 | . 2448 | . 3281 | . 4115 | . 4948 | 5781 | . 6615 | . 7448 | . 8281 | . 9115 | . 9948 |

## 217. British Weight Markings

If British weights are marked with four separate figures in one line, the numbers represent long tons of 2,240 pounds, hundredweights of 112 pounds, stone of 14 pounds, and pounds. Thus 4-2-3-7 equals 9,233 pounds; 3-2-2 equals 366 pounds.

## 218. Foreign Weights and Measures

Table 235. Foreign Weights and Measures

| Denominations | Where used | American equivalents | Denominations | Where used | A merican equivaients |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Almude | Portugal | 4.422 gals. | Fanega (dry) | Ecuador, Salvador- | 1.5745 bu. |
| Ardeb | Egypt | 5.6188 bu. | Fanega. | Chile.----.-.--- | 2.75268 bu. |
| Are | Metric | 0.02471 acre. | Fanega | Guatemala, Spain - | 1.53 bu . |
| Arr't'l or li'ra | Portugal | 1.0119 lbs . | Fanega | Mexico---------- | 2.57716 bu. |
| Arroba | Argentine Republic. | 25.32 lbs . | Fanega (double) | Uruguay | 7.776 bu. |
| Arroba | Brazil | 32.38 lbs . | Fanega (single) | Uruguay | 3.888 bu. |
| Arroba | Cuba | 25.36 lbs . | Fanega. | Venezuela | 3.334 bu. |
| Arroba | Paraguay | 25.32 lbs . | Fancga (liquid) | Spain_ | 16 gals . |
| Arroba | Venezuela | 25.40 lbs . | Feddan | Egypt------------ | 1.04 acres. |
| Arroba (liquid) | Cuba, Spain and Venezuela. | 4.263 gals. | Frall (rais's) <br> Frasco-...- | Spain_----------- Argentine Republic.- | 50 lbs . <br> 2.5098 liq. qts. |
| Arshine | Russia | 28 in . | Frasco | Mexico_--------- | 2.5 liq. qts. |
| Arshine (sq.) | Russia | 5.44 sq. ft. | Frasila | Zanzibar | 35 lbs . |
| Artel | Morocco | 1.12 lbs . | Fuder | Luxemburg | 264.18 gals. |
| Baril | Argentine Republic- | 20.077 gals. | Funt | Russia-----...-- | 0.9028 lb . |
|  | and Mexico...-- | 20.0787 gals. | Gallon | British Empire...- | 1.20094 U.S. gal. |
| Barrel | Malta (customs) .- | 11.2 gals. | Garnice. | Poland.-- | 1.0567 gal . |
| Berkovets. | Russia. | 361.128 lbs . | Gram. | Mctric | 15.432 grains. |
| Bongkal | Fed. Malay States_ | 832 grains. | Hectare | Metric | 2,471 acres. |
| Bouw | Sumatra | $7,096.5$ sq. metrs. | Hectolitre: Dry | Metric | 2.838 bu. |
| Bu | Japan_---------- | 0.12 inch. | Hectolitre: Liquid | Metric | 26.418 gals. |
| Bushel | British Empire.-.- | 1.03205 U.S. bu. | Jarib. | Persia (New) | 2.471 acres. |
| Caffiso | Malta | 5.40 gals. | Joch | Austria (Germany) | 1.422 acres. |
| Candy | India (Bombay) .-- | 569 lbs . | Joch | Hungary-------- | 1.067 acres. |
| Candy | India (Madras) - _ | 500 lbs . | Ken. | Japan. | 5.97 feet. |



Table 295. Foreign Weights and Measures-Continued

| Denominations | Where used | American equivalents | Denominations | Where used | American equivalents |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Marc | Bolivia_ | 0.507 lb . | Sagene | Russia | 7 feet. |
| Maund | India | 82 2-7 lbs. | Salm | Malta | 8.2 bu. |
| Metre | Metric | 39.37 inches. | Se | Japan_ | 0.02451 acre. |
| Mil | Denmark | 4.68 miles. | Seer | India | 2 2-35 lbs. |
| Mil (geographic) | Denmark | 4.61 miles. | Shaku | Japan_ | 11.9303 inches. |
| Milla | Nicaragua. | 1.1594 miles. | Sho | Japah_ | 1.91 liq. quarts. |
| Milla | Honduras. | 1.1493 miles. | Skalpund | Sweden | 0.937 lbs . |
| Mina (old) | Greece | 2.202 lbs . | Stone | British | 14 lbs . |
| Morgen | Prussia | 0.63 acre. | Sun | Japan. | 1.193 inches. |
| Oke | Egypt | 2.8052 lbs . | Tael Kuping | China | 575.64 grs. (troy). |
| Oke (Ocque) | Greece | 2.82 lbs . | Tan | Japan. | 0.25 acre. |
| Oke | Turkey | 2.828 lbs . | Tchetvert | Russia | 5.96 bu. |
| Pic. | Egypt. | 22.83 inches. | To | Japan. | 2.05 pecks. |
| Picul | Borneo \& Celebes.- | 135.64 lbs . | Ton | Space measure | $40 \mathrm{cu} . \mathrm{ft}$. |
| Picul | China | 1331/3 lbs. | Tonde cereals | Denmark | 3.9480 bu. |
| Picul | Java | 136.16 lbs . | Tonde Land. | Denmark | 1.36 acres. |
| Picul | Philippine Repub- | 139.44 lbs . | Tonne | France | 2204.62 lbs . |
|  | lic. |  | Tsubo | Japan | 35.58 sq. ft. |
| Pie | Argentine Repub- | 0.94708 foot. | Tsun | China | 1.26 inches. |
|  | lic. |  | Tunna (wheat) | Sweden | 4.5 bu. |
| Pie | Spain | 0.91416 foot. | Tunnland | Sweden | 1.22 acres. |
| Pik | Turkey | . 27.9 inches. | Vara | Argentine Repub- | 34.0944 inches. |
| Pood | Russia | 36.113 lbs . |  | lic. |  |
| Pund (lb) | Denmark | 1.102 lbs . | Vara | Costa Rica, Salva- | 32.913 inches. |
| Quart. | British Empire.--- | 1.20094 liq. qt. |  | dor. |  |
| Quart | British Empire.--- | 1.03205 dry qt. | Vara | Guatemala | 32.909 inches. |
| Quarter | Great Britain | 8.256 bu. | Vara | Honduras | 32.953 inches. |


| Quintal | Argentine Republic. | 101.28 lbs . | Vara. <br> Vara | NicaraguaChile and Pe | 33.057 inches. 32.913 inches. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Quintal | Brazil | 120.54 lbs. | Vara: | Cuba | 33.386 inches. |
| Quintal | Castile, Peru | 101.43 lbs . | Vara | Mexico | 32.992 inches. |
| Quintal | Chile. | 101.41 lbs . | Vedro | 'Russia | 2.707 gals. |
| Quintal | Mexico | 101.47 lbs . | Verst | Russia | 0.663 mile. |
| Quintal | Metric | 220.46 lbs . | Vloka. | Poland. | 41.50 acres. |
| Rottle | Israel | 6.35 lbs . | Wey-- | Scotland \& Ire- | 41.282 bu. |
| Sack (flour) | England. | 280 lbs. |  | $\bigcirc$ land. |  |

## 219. Properties of Materials

## a. Weights and Specific Gravities of Certain Materials.

Table 236. Weights and Specific Gravities

| Substance | $\begin{gathered} \text { Weight } \\ \text { (pounds per } \\ \text { cubic feet) } \end{gathered}$ | Specific gravity |
| :---: | :---: | :---: |
| BITUMINOUS SUBSTANCES: |  |  |
| Asphaltum. | 81 | 1. 1-1. 5 |
| Coal, anthracite | 97 | 1. 4-1. 7 |
| Coal, bituminous. | 84 | 1. 2-1. 5 |
| Coal, charcoal, pine. | 23 | 0. 28-0. 44 |
| Coal, charcoal, oak | 33 | 0. 47-0. 57 |
| Coal, coke. | 75 | 1. 0-1. 4 |
| Coal, lignite | 78 | 1. 1-1. 4 |
| Coal, peat, turf, dry | 47 | 0.65-0.85 |
| Graphite. | 131 | 1. 9-2. 3 |
| Paraffine. | 56 | 0.87-0.91 |
| Petroleum. | 54 | 0.87 |
| Petroleum, benzine | 46 | 0. 73-0.75 |
| Petroleum, gasoline | 42 | 0.66-0.69 |
| Petroleum, refined | 50 | 0. 79-0. 82 |
| Pitch. | 69 | 1. $07-1.15$ |
| Tar, bituminous | 75 | 1. 20 |
| BUILDING MATERIALS, VARIOUS: |  |  |
| Ashes, cinders. | 40-45 |  |
| Cement, portland, loose | 90 |  |
| Cement, portland, set. | 183 | 2. 7-3. 2 |
| Lime, gypsum, loose | 53-64 | ------- |
| Mortar, set | 103 | 1. 4-1.9 |
| Slags, bank screenings | 98-117 |  |
| Slags, bank slag-- | 67-72 | ---------- |
| Slags, machine slag | 96 | ---------- |
| Slags, slag sand.- | 49-55 |  |
| COAL AND COKE, PILED: |  |  |
| Coal, anthracite.---- | 47-58 |  |
| Coal, bituminous, lignite | 40-54 | ----------- |
| Coal, charcoal. | 10-14 | ----------- |
| Coal, coke.- | 23-32 | ----------- |
| Coal, peat, turf | 20-26 |  |
| EARTH, ETC., EXCAVATED: |  |  |
| Clay, damp, plastic-- | 110 | -------- |
| Clay, dry --- | 63 | ---------- |
| Clay and gravel, dry | 100 | ----------- |
| Earth, dry, loose. | 76 | --------- |
| Earth, dry, packed. | 95 | ---------- |
| Earth, moist, loose. | 78 | ------------ |
| Earth, moist, packed | 96 | ----------- |
| Earth, mud, flowing | 108 | ----------- |
| Earth, mud, packed | 115 |  |
| Riprap, limestone.- | 80-85 | ----------- |
| Riprap, sandstone. | 90 |  |
| Riprap, shale.- | 105 |  |


| Substance | Wcight (pounds per cubie fet) cuble feet) | Specific gravity |
| :---: | :---: | :---: |
| EARTH, ETC., EXCAVATED-Continued |  |  |
| Sand, gravel, dry, loose | 90-105 |  |
| Sand, gravel, dry, packed. | 100-120 |  |
| Sand, gravel, dry, wet... | 118-120 |  |
| EXCAVATIONS IN WATER: |  |  |
| Clay | 80 |  |
| River mud. | 90 |  |
| Sand or gravel | 60 |  |
| Sand or gravel and clay | 65 |  |
| Soil | 70 |  |
| Stone riprap. | 65 |  |
| GASES, VARIOUS: |  |  |
| Air, $0^{\circ} \mathrm{C} .760 \mathrm{~mm}$ - | . 08071 | 1 |
| Ammonia | . 0478 | 0. 5920 |
| Carbon dioxide. | . 234 | 1. 5291 |
| Carbon monoxide | . 0781 | 0. 9673 |
| Gas, illuminating | . 028 - 036 | 0. 35-0. 45 |
| Gas, natural | .038-. 039 | 0. 47-0. 48 |
| Hydrogen.- | . 00559 | 0. 0693 |
| Nitrogen. | . 0784 | 0. 9714 |
| Oxygen. | . 0892 | 1. 1056 |
| LIQUIDS, VARIOUS: |  |  |
| Alcohol, $100 \%$ - | 49 | 0.79 |
| Acid, muriatic, $\mathbf{4 0 \%}$ | 75 | 1. 20 |
| Acid, nitric, $91 \%$ - | 94 | 1. 50 |
| Acid, sulfuric, $87 \%$ | 112 | 1. 80 |
| Lye, soda, $66 \%$ | 106 | 1. 70 |
| Oils, mineral, lubricants | 57 | 0.90-0.93 |
| Oils, vegetable_ | 58 | 0.91-0.94 |
| Water, $4^{\circ} \mathrm{C}$. (maximum density) | 62. 428 | 1. 0 |
| Water, $100^{\circ} \mathrm{C}$ | 59.830 | U. 9584 |
| Water, ice. | 56 | 0. 88-0.92 |
| Water, sea | 64 | 1. 02-1. 03 |
| Water, snow, fresh fallen - | 8 | 0. 125 |
| MASONRY, ASHLAR: |  |  |
| Granite, syenite, gueiss. | 165 | 2. 3-3. 0 |
| Limestone, marble | 160 | 2. 3-2. 8 |
| Sandstone, bluestone. | 140 | 2. 1-2. 4 |
| MASONRY, BRICK: |  |  |
| Pressed brick | 140 | 2. 2-2. 3 |
| Common brick | 120 | 1. 8-2. 0 |
| Soft brick. | 100 | 1. 5-1. 7 |
| MASONRY, CONCRETE: | . |  |
| Cement, stonc, sand. | 144 | 2. 2-2. 4 |
| Cement, slag, etc.- | 130 | 1. 9-2.3 |
| Cement, cinder, etc. | 100 | 1. 5-1. 7 |
| MASONRY, DRPY RUBBLE: |  |  |
| Granite, syenite, gneiss | 130 | 1. 9-2.3 |
| Limestone, marble. | 125 | 1. 9-2.1 |
| Sandstone, bluestone. | 110 | 1. 8-1. 9 |

Table 236. Weights and Specific Gravities-Continued

| Substance | Welght (pounds per cuble feet) | Specific gravity |
| :---: | :---: | :---: |
| MASONRY, MORTAR RUBBLE: |  |  |
| Granite, syenite, gneiss. | 155 | 2. 2-2. 8 |
| Limestone, marble | 150 | 2. 2-2. 6 |
| Sandstone, bluestone. | 130 | 2. 0-2. 2 |
| METALS, ALLOYS, ORES: |  |  |
| Aluminum, cast, hammered. | 165 | 2. 55-2. 75 |
| Brass, cast, rolled. | 534 | 8. 4-8. 7 |
| Bronze, 7.9 to $14 \% \mathrm{Sn}$. | 509 | 7. 4-8.9 |
| Bronze, aluminum. | 481 | 7. 7 |
| Copper, cast, rolled. | 556 | 8. 8-9. 0 |
| Copper ore, pyrites. | 262 | 4. 1-4. 3 |
| Gold, cast, hammered. | 1205 | 19. $25-19.3$ |
| Iron, cast, pig. | 450 | 7. 2 |
| Iron, ferrosilicon. | 437 | 6. 7-7. 3 |
| Iron, spiegeleiser. | 468 | 7. 5 |
| Iron, wrought | 485 | 7. 6-7. 9 |
| Iron ore, hematite. | 325 | 5. 2 |
| Iron ore, hematite in bank. | 160-180 |  |
| Iron ore, hematite loose | 130-160 |  |
| Iron ore, limonite | 237 | 3. 6-4. 0 |
| Iron ore, magnetite | 315 | 4. 9-5. 2 |
| Iron slag. | 172 | 2. 5-3. 0 |
| Lead_- | 710 | 11. 37 |
| Lead ore, galena | 465 | 7. 3-7. 6 |
| Magnesium, alloys | 112 | 1. 74-1. 83 |
| Manganese. | 475 | 7. 2-8. 0 |
| Manganese ore, pyrolusite | 259 | 3. 7-4. 6 |
| Mercury-- | 849 | 13. 6 |
| Monel metal | 556 | 8. 8-9. 0 |
| Nickel.. | 565 | 8. 9-9. 2 |
| Platinum, cast, hammered | 1330 | 21. 1-21. 5 |
| Silver, cast, hammered. | 656 | 10. 4-10. 6 |
| Steel, rolled...- | 490 | 7. 85 |
| Tin, cast, hammered | 459 | 7. 2-. 75 |
| Tin ore, cassiterite | 418 | 6. 4-7. 0 |
| Zinc, cast, rolled... | 440 | 6. 9-7. 2 |
| Zinc ore, blende. | 253 | 3. 9-4. 2 |
| MINERALS: |  |  |
| Asbestos | 153 | 2. 1-2. 8 |
| Barite. | 281 | 4. 50 |
| Basalt | 184 | 2. 7-3. 2 |
| Bauxite. | 159 | 2.55 |
| Borax | 109 | 1. 7-1. 8 |
| Chalk | 137 | 1. 8-2. 6 |
| Clay, marl | 137 | 1. 8-2. 6 |
| Dolomite. | 181 | 2. 9 |
| Feldspar, orthoclase | 159 | 2. 5-2. 6 |
| Gneiss, serpentine. | 159 | 2. 4-2. 7 |
| Granite, syenite. | 175 | 2. 5-3. 1 |

Table 236. Weights and Specific Gravities-Continued

| Substance | $\begin{aligned} & \text { Weight } \\ & \text { (pounds per } \\ & \text { cubic feet) } \end{aligned}$ | Specific gravity |
| :---: | :---: | :---: |
| MINERALS-Continued |  |  |
| Greenstonc, trap. | 187 | 2. 8-3. 2 |
| Gypsum, alabaster. | 159 | 2. 3-2. 8 |
| Hornblende... | 187 | 3. 0 |
| Limestone, marble | 165 | 2. 5-2. 8 |
| Magnesite | 187 | 3. 0 |
| Phosphate rock, apatite | 200 | 3. 2 |
| Porphyry --- | 172 | 2. 6-2.9 |
| Pumice, natural | 40 | 0. 37-0. 90 |
| Quartz, flint. | 165 | 2. 5-2. 8 |
| Sandstone, bluestone | 147 | 2. $2=2.5$ |
| Shale, slate. - | 175 | 2. 7-2. 9 |
| Soapstone, talc | 169 | 2. 6-2. 8 |
| SOLIDS, VARIOUS: |  |  |
| Cereals, barley (bulk) | 39 |  |
| Cereals, corn, rye (bulk) | 48 | --- |
| Cereals, oats (bulk) | 32 | -------- |
| Cereals, wheat (bulk) | 48 |  |
| Cotton, flax, hemp. | 93 | 1. 47-1. 50 |
| Fats. | 58 | 0.90-0.97 |
| Flour, loose | 28 | 0. 40-0. 50 |
| Flour, pressed. | 47 | 0. 70-0. 80 |
| Glass, common | 156 | 2. 40-2. 60 |
| Glass, crystal | 184 | 2. $90-3.00$ |
| Glass, plate or crown | 161 | 2. 45-2. 72 |
| Hay and straw (bales) | 20 | -- |
| Leather | 59 | 0. 86-1. 02 |
| Paper | 58 | 0. 70-1. 15 |
| Potatoes, piled | 42 |  |
| Rubber, caoutchouc | 59 | 0.92-0.96 |
| Rubber goods. | 94 | - 1. 0-2. 0 |
| Salt, granulated, piled | 48 | --------- |
| Saltpeter. | 67 |  |
| Starch_ | 96 | 1. 53 |
| Sulfur | 125 | 1. 93-2. 07 |
| Wool | 82 | 1. 32 |
| Stone, Quarried, PILED: |  |  |
| Basalt, granite, gneiss. | 96 | --------- |
| Greenstone, hornblende. | 107 |  |
| Limestone, marble, quartz | 9 |  |
| Sandstone . | 82 |  |
| Shale_- | 92 |  |
| TIMBER, U.S. SEASONED: |  |  |
| 15 to $20 \%$; green timber up to $50 \%$ ): |  |  |
| Ash, white, red.----------------------1 | 40 | 0. 62-0. 65 |
| Cedar, white, red. | 22 | 0. 32-0. 38 |
| Chestnut | 41 | 0. 66 |
| Cypress. | 30 | 0. 48 |

Table 236. Weights and Specific Gravities-Continued

| Substance | Weight (pounds per eubie feet) | Speeifle gravity |
| :---: | :---: | :---: |
| TIMBER, U.S. SEASONED-Continued |  |  |
| Elm, white | 45 | 0.72 |
| Fir, Douglas Spruce | 32 | 0.51 |
| Fir, eastern. | 25 | 0. 40 |
| Hemlock. | 29 | 0. 42-0. 52 |
| Hickory | 49 | 0.74-0.84 |
| Locust. | 46 | 0.73 |
| Maple, hard | 43 | 0.68 |
| Maple, white | 33 | 0.53 |
| Oak, chestnut. | 54 | 0. 86 |
| Oak, live -- | 59 | 0.95 |
| Oak, red, black | 41 | 0.65 |
| Oak, white.- | 46 | 0. 74 |
| Pine, Oregon- | 32 | 0.51 |
| Pine, red | 30 | 0. 48 |
| Pine, white.- | 26 | 0. 41 |
| Pine, yellow, longleaf.-- | 44 | 0. 70 |
| Pine, yellow, shortleaf. | 38 | 0.61 |
| Poplar.--- | 30 | 0. 48 |
| Redwood, California | 26 | 0. 42 |
| Spruce, white, black | 27 | 0. $40-0.46$ |
| Walnut, black... | 38 | 0. 61 |
| Walnut, white. | 26 | 0.41 |

The speeifie gravities of solids and llquids refer to water at $4^{\circ} \mathrm{C}$. and 760 mm . pressure. The weights per cuble foot are derived from average speelfic gravities, exeept where stated that weights are for bulk, heaped or loose material, etc.
b. Weights of Certain Building Materials.

Table 237. Weights of Building Materials

| Material | Weight, pounds per square foot |
| :---: | :---: |
|  |  |
| CEILINGS: |  |
|  | 10 |
|  | 5 |
|  | 8 |
|  | 8 |
|  | 3 |
| Suspended, metal lath and plaster. | 10 |
| FLOORS: |  |
| Cement finish, per inch thick | 12 |
| Cinder concrete, per inch thick | 9 |
| Cinder concrete fill, per inch thick | 5 |
| Gypsum slab, per inch thick. | 5 |
| Hardwood flooring, $7 / 8^{\prime \prime}$ thick | 4 |
| Sheathing, white, red, or Oregon pine, spruce, or hemlock, $7 / 8^{\prime \prime}$ thick | 21/2 |

Table 2s7. Weights of Building Materials—Continued

| Material | Weight, pounds per square foot |
| :---: | :---: |
| FLOORS-Continued |  |
| Sheathing, yellow pine, $1^{\prime \prime}$ thick | 4 |
| Terrazzo, tile, mastic, linoleum, per inch thick, including base_ | 12 |
| Wood block, creosoted, $3^{\prime \prime}$ thick | 15 |
| PARTITIONS: |  |
| Channel studs, metal lath, cement plaster, solid, $2^{\prime \prime}$ thick.-- | 20 |
| Hollow clay tile, $\mathbf{2}^{\prime \prime}$ - | 13 |
| Hollow clay tile, $3^{\prime \prime}$ - | 16 |
| Hollow clay tile, $4^{\prime \prime}$------------------------------------------ | 18 |
| Hollow clay tile, $5^{\prime \prime}$ - | 20 |
| Hollow clay tile, $6^{\prime \prime}$--------------------------------------- | 25 |
| Hollow clay tile, $8^{\prime \prime}$ - | 30 |
| Hollow clay tile, $10^{\prime \prime}$ - | 35 |
| Plaster, $32^{\prime \prime}$, on gypsum block or clay tile (one side) | 4 |
| Solid gypsum block, $2^{\prime \prime}$ | $91 / 2$ |
| Solid gypsum block, $3^{\prime \prime}$ | 13 |
| Steel partitions.- |  |
| Studs, $2^{\prime \prime} \times 4^{\prime \prime}$ plaster board, $1 / 2^{\prime \prime}$ plaster both sides | 18 |
| Studs, $2^{\prime \prime} \times 4^{\prime \prime}$ wood or metal lath, $34^{\prime \prime}$ plaster both sides. | 18 |
| ROOFS: |  |
| Corrugated metal | (Par. 180) |
| Ready roofing, 3 ply. | 1 |
| Roofing felt, 3 ply and gravel. | 512 |
| Roofing felt, 5 ply and gravel | 61/2 |
| Roofing felt, 3 ply and slag | 51/2 |
| Roofing felt, 5 ply and slag- | 51/2 |
| Shingles, wood. |  |
| Tile or slate | 5-20 |
| WALLS: |  |
| Brick, $9^{\prime \prime}$ thick. | 84 |
| Brick, $13^{\prime \prime}$ thick | 121 |
| Brick, $18^{\prime \prime}$ thick | 168 |
| Brick, $22^{\prime \prime}$ thick | 205 |
| Brick, $26^{\prime \prime}$ thick | 243 |
| Brick $4^{\prime \prime}$, tile backing $4^{\prime \prime}$ | 60 |
| Brick $4^{\prime \prime}$, tile backing $8^{\prime \prime}$ | 75 |
| Brick $8^{\prime \prime}$, tile backing $4^{\prime \prime}$ | 100 |
| Brick $9^{\prime \prime}$, tile backing $8^{\prime \prime}$ | 115 |
| Corrugated metal siding. | (Par. 180) |
| Limestone $4^{\prime \prime}$, brick $9^{\prime \prime}$. | 140 |
| Limestone $4^{\prime \prime}$, brick $13^{\prime \prime}$ | 175 |
| Limestone $4^{\prime \prime}$, tile $8^{\prime \prime}$ | 90 |
| Limestone $4^{\prime \prime}$, tile $12^{\prime \prime}$ - | 100 |
| Wall tile, $6^{\prime \prime}$ thick | 30 |
| Wall tile, $8^{\prime \prime}$ thick_ | 33 |
| Wall tile, $10^{\prime \prime}$ thick | 40 |
| Wall tile, $12^{\prime \prime}$ thick | 45 |
| Windows, glass, frame, and sash_ | 8 |

Table 238. Strengths of Materials, Metals and Alloys

| Material | Stress in kips per square inch |  |  |  |  | Modulus of clasticity (pounds per square inch) | Fiongation pereent |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Tension ultimate | Elastic limit | Compression ultimate | Bending uitimate | Shcarlng ultimatc |  |  |
| Aluminum, bars, sheets | 24-28 | 12-14 |  |  |  |  |  |
| Aluminum, wire, annealed | 20-35 | 14 |  |  |  |  |  |
| Brass, $50 \%$ Zn- | 31 | 17.9 | 117 | 33.5 |  |  | 5 |
| Brass, cast, common | 18-24 |  | 30 | 20 | 36 | 9, 000, 000 |  |
| Brass, wire, hard | 80 |  |  |  |  |  |  |
| Brass, wire, annealed | 50 | 16 |  |  |  | 14,000, 000 |  |
| Bronze, aluminum 5 to $71 / 2 \%$ | 75 | 40 | 120 |  |  |  |  |
| Bronze, Tobin, cast, $38 \% \mathrm{Zn}$ | 66 |  |  |  |  |  |  |
| Bronze, Tobin, rolled, $11 / 2 \%$ Sn_ | 80 | 40 |  |  |  | 14,500, 000 |  |
| Bronze, Tobin, c. rolled, $1 / 3 \% \mathrm{~Pb}$ | 100 |  |  |  |  |  |  |
| Copper, plates, rods, bolts_ | 32-35 | 10 | 32 |  |  |  |  |
| Iron, cast, gray | 18-24 |  |  | 25-33 |  |  |  |
| Iron, cast, malleable_ | 27-35 | 15-20 | 46 | 30 | 40 |  |  |
| Iron, wrought, shapes-. | 48 | 26. | Tensile | Tensile | 5/6 tensile. | 28, 000, 000 |  |
| Steel, bridges, buildings, ships | 60-72 | 33 | Tensile | Tensile. | 3/4 tensile. | 29, 000, 000 |  |
| Steel, cars. | 50-65 | $1 / 2$ tensile. | Tensile. | Tensile | $3 / 4$ tensile. | 29, 000, 000 |  |
| Steel, cast, hard. | 80 | 36 | Tensile_ | Tensile. | 3/4 tensile | 29, 000, 000 | ${ }^{1} 17$ |
| Steel, cast, medium | 70 | 31.5 | Tensile | Tensile | 3/4 tensile. | 29, 000, 000 | ${ }^{1} 20$ |
|  | 60 | 27. | Tensile | Tensile_ | 3/4 tensile | 29, 000, 000 | ${ }^{1} 24$ |
| Steel, locomotives, stationary boilers | 55-65 | 1/2 tensilc | Tensile. | Tensile. | $3 / 4$ tensile | 29, 000, 000 |  |
| Steel, plates for cold pressing | 48-58 | $1 / 2$ tensile. | Tensile. | Tensile | 3/4 tensile | 29, 000, 000 |  |
| Steel, rivet, boiler | 45-55 | 1/2 tensile. | Tensile | Tensile | 3/4 tensile | 29, 000, 000 |  |
| Steel, rivet, bridges, buildings, locomotives, cars. | 52-62 | 28. | Tensile. | Tensile | 3/4 tensile | 29, 000,000 |  |


$12^{\prime \prime}$ gage length
$1,500,000$
tensile strength, $8^{\prime \prime}$ gage length

Table 238. Strengths of Materials, Building Materials

| Material | A verage ultimate stress (pounds per square inch) |  |  | Safe working stress (pounds per square inch) |  |  | Modulus of clasticlty (pounds per square inch) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Compression | ${ }^{\text {- }}$ Tension | Bending | Compresslon | Bearing | Shearing |  |
| Masonry, brick, common. | 10, 000 | 200 | 600 |  |  |  |  |
| Masonry, granite.- |  |  |  | 420 | 600 |  |  |
| Masonry, limestone, bluest |  |  |  | 350 | 500 |  |  |
| Masonry, sandstone |  |  |  | 280 | 400 |  |  |
| Masonry, rubble |  |  |  | 140 | 250 |  |  |
| Ropes, cast steel hoisting- |  | 80, 000 |  |  |  |  |  |
| Ropes, manila |  | 8, 000 |  |  |  |  |  |
| Ropes, standing, derrick |  | 70, 000 |  |  |  |  |  |
| Stone, bluestone. | 12, 000 | 1, 200 | 2,500 | 1, 200 | 1, 200 | 200 | 7, 000, 000 |
| Stone, granite, gneiss | 12, 000 | 1, 200 | 1, 600 | 1, 200 | 1, 200 | 200 | 7, 000, 000 |
| Stone, limestone, marble | 8, 000 | 800 | 1,500 | 800 | 800 | 150 | 7, 000, 000 |
| Stone, sandstone. | 5, 000 | $\therefore 150$ | 1,200 | 500 | 500 | 150 | 3, 000, 000 |
| Stone, slate.. | 10, 000 | $\therefore 3,000$ | 5, 000 | 1, 000 | 1, 000 | 175 | 14, 000, 000 |

d. Coefficients of Expansion of Certain Materials. The coefficient of linear expansion ( $\epsilon$ ) of a material is the change in length, per unit of length, for a change of one degree of temperature. The coefficient of surface expansion is approximately two times the linear coefficient, and the coefficient of volume expansion, for solids, is approximately three times the linear coefficient.
(1) A bar, free to move, will increase in length with an increase in temperature and will decrease in length with a decrease in temperature. The change in length will be $\epsilon t l$, where $\leftrightarrows$ is the coefficient of linear expansion, $t$ the change in temperature, and $l$ the length. If the ends of a bar are fixed, a change in temperature ( t ) will cause a change in the unit stress of E $\epsilon$, and in the total stress of AEct, where $A$ is the cross sectional area of the bar and $E$ the modulus of elasticity.
(2) Table 239 gives the coefficient of linear expansion for $100^{\circ}$, of 100 times the value indicated above.
Example: A piece of medium steel is exactly 40 feet long at $60^{\circ} \mathrm{F}$. Find the length at $90^{\circ} \mathrm{F}$. assuming the ends free to move.
Change of length $=\epsilon \mathrm{tl}=\frac{.00067 \times 30 \times 40}{100}=.00804$ foot.
(3) The length at $90^{\circ} \mathrm{F}$. is 40.00804 feet.

Example: A piece of medium steel is exactly 40 feet long and the ends are fixed. If the temperature increases $30^{\circ} \mathrm{F}$., what is the resulting change in the unit stress?
$\begin{aligned} \text { Change in unit stress }=\mathrm{E}_{\epsilon} \mathrm{t} & =\frac{29,000,000 \times 0.00067 \times 30}{100} \\ & =5830 \text { lbs. per sq. in. }\end{aligned}$

| Materials | Linear expansion |  | Materials | Linear expansion |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Centigrade | Fahrenheit |  | Centigrade | Fahrenheit |
| METALS AND ALLOYS: |  |  | METALS AND ALLOYS-Continued |  |  |
| Aluminum, wrought. | 0.00231 | 0. 00128 | Steel, stainless, 18-8..---.-.-.-. | . 00178 | . 00099 |
| Brass | . 00188 | . dopl04 | Zinc, rolled.-.- | . 00311 | . 00173 |
| Bronze. | . 00181 | . 00101 | STONE AND MASONRY: |  |  |
| Copper | . 00168 | . 000093 | Ashlar masonry | . 00063 | . 00035 |
| Iron, cast, gray | . 00106 | . 00059 | Brick masonry----------------------- | . 00055 | . 00031 |
| Iron, wrought. | . 00120 | . 000067 | Cement, portland | . 00107 | . 00059 |
| Iron, wire | . 00124 | . 00069 | Concrete.- | . 00143 | . 00079 |
| Lead | . 00286 | . 00159 | Granite. | . 00084 | . 00047 |
| Magnesium, various alloys | . 0029 | . 0016 | Limestone. | . 00080 | . 00044 |
| Nickel. | . 00126 | . 00070 | Marble | . 00100 | . 00056 |
| Steel, cast | . 00110 | . 00061 | Plaster | . 00166 | . 00092 |
| Steel, hard | . 00132 | . 00073 |  | . 00063 | . 00035 |
| Steel, medium | . 00120 | . 000067 |  | . 00110 | . 00061 |
| Steel, soft | . 00110 | . 00061 | Slate | . 00104 | . 000058 |
| TIMBER |  | \% | TIMBER |  |  |
|  |  |  |  |  |  |
| Fir------------- | [ $\begin{array}{r}0.00037 \\ 00064\end{array}$ | 0. 00021 | Fir----------- | 0. 0058 | 0.0032 |
| Maple $\qquad$ parallel to fiber | $\left\{\begin{array}{l}.00064 \\ \hline 00049\end{array}\right.$ | . 09036 | Maple_--.-.-- | . 0048 | . 0027 |
| Oak----------- | . 00049 | . 00027 | Oak___-...-- | . 0054 | . 0030 |
| Pine.---------- | (.00054 | . 00030 | . Pine----------- | ( . 0034 | . 0019 |

EXPANSION OF WATER
Maximum Density $=1$

| ${ }^{\circ} \mathrm{C}$. | Volume | ${ }^{\circ} \mathrm{C}$. | Volume | ${ }^{\circ} \mathrm{C}$. | Volume | ${ }^{\circ} \mathrm{C}$. | Volume |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0. | 1. 000126 | 20 | 1. 001732 | 50. | 1.011877 | 80. | 1. 029003 |
| 4 | 1. 000000 | 30 | 1. 004234 | 60 | 1. 016954 | 90 | 1. 035829 |
| 10. | 1. 000257 |  | 1. 007627 | 70. | 1. 022384 | 100. | 1. 043116 |

220. Density of Gases

Table 240. Density of Gases

| Gas | Weight |  | Speeifle gravity |  |
| :---: | :---: | :---: | :---: | :---: |
|  | Orams per liter | Pounds per cubic foot | $A$ ir $=0$ | $0=1$ |
| Air | 1. 2930 | 0. 00872 | 1. 0000 | 0. 9048 |
| Acetylene | 1. 1791 | 0. 07361 | 0. 9119 | 0. 8251 |
| Ammonia | 0. 7708 | 0. 04812 | 0. 5961 | 0. 5394 |
| Argon | 1. 7809 | 0. 11118 | 1. 3773 | 1. 2462 |
| Bromine | 7. 14 | 0. 446 | 5. 52 | 5. 00 |
| Butanc. | 2. 594 | 0. 1619 | 2. 006 | 1. 815 |
| Carbon dioxide | 1. 9768 | 0. 12341 | 1. 5289 | 1. 3833 |
| Carbon monoxide_ | 1. 2504 | 0. 07806 | 0. 9671 | 0. 8750 |
| Chlorine | 3. 221 | 0. 2011 | 2. 491 | 2. 254 |
| Cial gas | 0. 41-0.96 | 0. 026-0.060 | 0. 32-0. 74 | 0. 29-0.67 |
| Cyanogen | 2. 323 | 0. 1450 | 1. 797 | 1. 626 |
| Ethanc | 1. 3562 | 0. 08467 | 1. 0489 | 0. 9490 |
| Ethylene | 1. 2609 | 0. 07872 | 0. 9752 | 0. 8823 |
| Fluorine | 1. 70 | 0. 106 | 1. 31 | 1. 19 |
| Helium | 0. 1785 | 0.01115 | 0. 1381 | 0. 1249 |
| Hydrobromic acid | 3. 616 | 0. 2257 | 2. 797 | 2. 530 |
| Hydrochloric acid | 1. 6398 | 0. 1023 | 1. 2682 | 1. 1475 |
| Hydrolluoric acid. | 0. 922 | 0. 0576 | 0. 713 | 0. 645 |
| Hydrogen_ | 0. 08987 | 0. 00561 | 0. 06950 | 0. 06289 |
| Hydrogen sulfide | 1. 538 | 0. 09602 | 1. 189 | 1. 076 |
| Krypton. | 3. 708 | 0. 2315 | 2. 868 | 2. 595 |
| Methanc | 0. 7168 | 0. 04475 | 0. 5544 | 0. 5016 |
| Methyl chloride | 2. 304 | 0. 1438 | 1. 782 | 1. 612 |
| Methyl ether | 2. 110 | 0.1317 | 1. 632 | 1. 477 |
| Neon_ | 0. 9002 | 0. 05620 | 0. 6962 | 0. 6299 |
| Nitrogen | 1. 2507 | 0. 07808 | 0. 9673 | 0. 8752 |
| Nitric oxide | 1. 3402 | 0. 08367 | 1. 0365 | 0. 9378 |
| Nitrous oxide | 1. 9777 | 0. 12347 | 1. 5296 | 1. 3839 |
| Oxygen. | 1. 42905 | 0. 08921 | 1. 1052 | 1. 0000 |
| Propane | 2. 0196 | 0. 12608 | 1. 5620 | 1. 4132 |
| Steam at $100^{\circ} \mathrm{C}$ | 0. 598 | 0. 0373 | 0. 462 | 0. 418 |
| Sulphur dioxide. | 2. 9266 | 0. 18270 | 2. 2634 | 2. 0479 |
| Kenon. | 5. 851 | 0. 3653 | 4. 525 | 4. 094 |

Notes. The gases in this table, or the elements of which they are composed. are the isotopes or mistures of isotopes normally occurring in nature.

## 221. Contents of Horizontal Tanks

The cubic content of a horizontal cylindrical tank of circular or clliptical cross section is given by the formula-

$$
C=\frac{\pi}{4}\left(\frac{d^{2} l}{231}\right)=0.0034 d^{2} l
$$

where $C$ is the capacity in gallons and $d$ and $l$ are, respectively, the diameter and the length in inches. For a tank partially filled with
liquid, the volume of liquid as a percentage of the total capacity is related to the depth of liquid as a percentage of the total depth (diameter) as shown in table 241. Use columns 1 and $1 a$ if the percentage depth is 50 percent or less; columns 2 and $2 a$ if greater than 50 percent.

Table 241. Capacilies of Partially Filled Tanks

| Percent of depth |  | Percent of capacity |  | Percent of depth |  | Percont of capacity |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1-filled | 2-unfilled | 1a-filled | 2a-unflled | 1-filled | $2-$ unflled | 19-filled | 2a-unfilled |
| 1 | 99 | 0.20 | 99. 80 | 26 | 74 | 20.73 | 79.27 |
| 2 | 98 | 0. 50 | 99. 50 | 27 | 73 | - 21.86 | 78.14 |
| 3 | 97 | 0.90 | 99. 10 | 28 | 72 | 23. 00 | 77.00 |
| 4 | 96 | 1. 34 | 98.66 | 29 | 71 | 24. 07 | 75.93 |
| 5 | 95 | 1.87 | 98. 13 | 30 | 70 | 25. 31 | 74.69 |
| 6 | 94 | 2.45 | 97. 55 | 31 | 69 | 26. 48 | 73.52 |
| 7 | 93 | 3. 07 | 96. 93 | 32 | 68 | 27.66 | 72.34 |
| 8 | 92 | 3. 74 | 96. 26 | 33 | 67 | 28. 84 | 71.16 |
| 9 | 91 | 4. 45 | 95. 55 | 34 | 66 | 30. 03 | 69.97 |
| 10 | 90 | 5. 20 | 94. 80 | 35 | 65 | 31. 19 | 68.81 |
| 11 | 89 | 5. 98 | 94. 02 | 36 | 64 | 32. 44 | 67.56 |
| 12 | 88 | 6. 80 | 93. 20 | 37 | 63 | 33. 66 | 66. 34 |
| 13 | 87 | 7.64 | 92. 36 | 38 | 62 | 34. 90 | 65. 10 |
| 14 | 86 | 8. 50 | 91. 50 | 39 | 61 | 36. 14 | 63.86 |
| 15 | 85 | 9. 40 | 90.60 | 40 | 60 | 37. 39 | 62.61 |
| 16 | 84 | 10.32 | 89. 68 | 41 | 59 | 38. 64 | 61.36 |
| 17 | 83 | 11. 27 | 88. 73 | 42 | 58 | 39. 89 | 60.11 |
| 18 | 82 | 12. 24 | 87.76 | 43 | 57 | 41. 14 | 58.86 |
| 19 | 81 | 13.23 | + 86.77 | 44 | 56 | 42. 40 | 57.60 |
| 20 | 80 | 14. 23 | + 85.77, | 45 | 55 | 43. 66 | 56.34 |
| 21 | 79 | 15.26 | 84.74 | 46 | 54 | 44. 92 | 55.08 |
| 22 | 78 | 16. 32 | 83.68 | 47 | 53 | 46. 19 | 53.81 |
| 23 | 77 | 17. 40 | 82. 60 | 48 | 52 | 47. 45 | 52.55 |
| 24 | 76 | 18. 50 | 81. 50 | 49 | 51 | 48. 73 | 51.27 |
| 25 | 75 | 19.61 | 80.39 | 50 | 50 | 50.00 | 50.00 |

## 222. Volume of Piled. Sand or Gravel

To obtain the capacity of a conical pile, enter figure 110 on the horizontal line at the bottom with the height of the pile in feet. Proceed upward to the point where the proper curve intersects this vertical line. Proceed horizontally from this intersection to the column at the left and read capacity in tons. For example, a 24 -foothigh conical pile of gravel will hold 1,770 tons. (See arrow and dotted line on chart.) For a pile shaped as shown, add to the capacity of one conical pile the capacity of an A-shaped pile from the "scale in tons per linear foot of storage." For example (see arrow and dotted line) an A-shaped pile of sand 22 feet high holds 28.8 tons per linear foot.


Figure 110. Volume of piled sand or gravel.

## 223. Safe Loads on Wood Piles

Safc loads may be limited by maximum values considered allowable, by skin friction, or by column action. The values obtained are approximations only.
a. Maximum Allowable Loads. All pile formulas being empirical, maximum loads per pile for semipermanent structures are normally limited to the following:

| Pile diameter, inches ${ }^{\text {a }}$ |  | 8 | 10 | 12 | 14 | 16 |
| :--- | ---: | ---: | :--- | :--- | :--- | :--- |
| Maximum allowable load, tons.-...-. | 16 | 24 | 30 | 36 | $42^{\text {b }}$ |  |

b. Skin Friction. This value for safe load, which may govern for piles in soft formations, is obtained from data or test loads as follows:
(1) Driving data.
(a) Piles driven by drophammer:

$$
P=\frac{2 W h}{s+1.0}
$$

(b) Piles driven by single-aeting steam hammer:

$$
P=\frac{2 W_{t} h}{s+0.1}(t=\text { stroke of ram in feet })
$$

(c) Piles driven by double-acting steam hammer:

$$
P=\frac{2 E}{s+0.1}
$$

Where $P=$ safe load in pounds per pile
$\mathrm{W}=$ weight of drophammer or ram
$h=$ fall of drophammer in feet or stroke of ram in inches
$s=$ average penctration in inehes per blow for the last 6 blows of drophammer or 20 blows of steam hammer
$E=$ driving energy in foot-pounds per blow of double-aeting hammer, estimated as follows:

(2) Test loads. Normally test loads are increased 5 tons at 48 -hour intervals. The maximum safe load per pile is onc-half the load which in 48 hours produees settlement of $1 / 2$ inch, not counting any settlement produced during and immediately after applying the increment.
c. Column Action. Piles with considerable unsupported length or with eccentric or lateral loads may require design as columns partially

[^50]fixed at one end, using formulas given in chapter 9 . The fixation must be estimated. It may be high or, as for piles bearing on rock with light overburden, very low.

## 224. Conversion Factors

Table 242. Conversion Factors

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| Acres | 43,560 | square feet. |
| aeres. | 4,047 | square meters. |
| acres | $1.562 \times 10^{-3}$ | square miles. |
| acres | 5645.38 | square varas. |
| aeres | 4,840 | square yards. |
| a cre-feet | 43,560 | eubic-feet. |
| ares | 0.02471 | acres. |
| ares | 100 | square meters. |
| atmospheres | 76.0 | cms. of mercury. |
| atmospheres | 29.92 | inches of mercury. |
| atmospheres. | 33.90 | feet of water. |
| atmospheres | 10,333 | kgs. per square meter. |
| atmospheres | 14.70 | pounds per sq. ineh. |
| atmospheres | 1.058 | tons per sq. foot. |
| Bars | $9.870 \times 10^{-7}$ | atmospheres. |
| bar | 1 | dynes per sq. cm. |
| bar | 0.01020 | kgs. per square meter |
| bars | $2.089 \times 10^{-3}$ | pounds per sq. foot. |
| bars | $1.450 \times 10^{-5}$ | pounds per sq. inch. |
| board-feet | 144 sq. in. $\times 1 \mathrm{in}$. | cubic inches. |
| British thermal units | 0.2520 | kilogram-calories. |
| British thermal units_ | 777:5 | foot-pounds. |
| British thermal units | $3.927 \times 10^{-4}$ | horse-power-hours. |
| British thermal units. | 1.054 | joules. |
| British thermal units_ | 107.5 | kilogram-meters. |
| British thermal units | $2.928 \times 10^{-4}$ | kilowatt-hours. |
| B.t.u. per min_ | 12.96 | foot-pounds per sec. |
| B.t.u. per min_ | 0.02356 | horse-power. |
| B.t.u. per min | 0.01757 | kilowatts. |
| B.t.u. per min | 17.57 | watts. |
| B.t.u. per sq. ft. per | 0.1220 | watts per square ineh. |
| bushels. | 1.244 | eubic feet. |
| bushels | 2,150 | eubic inches. |
| bushels. | 0.03524 | eubic meters. |
| bushels | 4 | peeks. |
| bushels. | 64 | pints (dry). |
| bushels. | 32 | quarts (dry). |
| Centares. | 1 | square meters. |
| centigrams. | 0101 | grams. |
| eentiliters. | 0.01 | liters. |
| eentimeter | 0.3937 | inches. |
| eentimeters | 0.01 | meters. |
| eentimeters | 393.7 | mils. |

Table 242. Conversion Factors-Continued

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| contimete | 10 | millimeters. |
| centimeters-dynes | $1.020 \times 10^{-3}$ | centincter-grams. |
| centimeter-dyncs | $1.020 \times 10^{-8}$ | meter-kilograms. |
| eentimeter-dynes | $7.376 \times 10^{-8}$ | pound-feet. |
| centimeter-grams | 980.7 | centimeter-dynes. |
| centimeter-grams | $10^{-5}$ | meter-kilograms. |
| centimeter-grams | $7.233 \times 10^{-5}$ | pound-feet. |
| centimeters of mercury | 0.01316 | atmospheres. |
| centimeters of mercury | 0.4461 | feet of water. |
| centimetcrs of mercury | 136.0 | kgs . per square meter. |
| centimeters of mercury | 27.85 | pounds per sq. foot. |
| centimeters of mereury | 0.1934 . | pounds per sq. inch. |
| centimeters per second | 1.969 | feet per minute. |
| centimeters per sccond | 0.03281 | fect per second. |
| centimeters per second | 0.036 | kilometers per hour. |
| centimeters per second | 0.6 | meters per minute. |
| centimeters per second | 0.02237 | miles per hour. |
| centimeters per sccond | $3.728 \times 10^{-4}$ | miles per minute. |
| cms. per sec. per scc | 0.03281 | feet per see. per see. |
| cms. per sec. per sec | 0.036 | kms . per hour per sec. |
| cms. per scc. per'sec | 0.02237 | miles per hour per sec. |
| circular mils | $5.067 \times 10^{-6}$ | square centimeters. |
| cireular mils | $7.854 \times 10^{-7}$ | square inches. |
| circular mils | 0.7854 | square mils. |
| cord-feet | $4 \mathrm{ft} . \times 4 \mathrm{ft} . \times 1 \mathrm{ft}$. | cubic feet. |
| cords | $8 \mathrm{ft} . \times 4 \mathrm{ft} . \times 4 \mathrm{ft}$. | cubic feet. |
| cubie centimeter | $3.531 \times 10^{-5}$ | cubic feet. |
| cubic centimeters | $6.102 \times 10^{-2}$ | cubic inches. |
| cubie centimeter | $10^{-8}$ | cubic meters. |
| cubic centime | $1.308 \times 10^{-6}$ | eubic yards. |
| cubic centimeter | $2.642 \times 10^{-4}$ | gallons. |
| cubic centimeter | $10^{-3}$ | liters. |
| cubic centimet | $2.113 \times 10^{-3}$ | pints (liq.) |
| cubic centimeter | $1.057 \times 10^{-3}$ | quarts (liq.) |
| cubic fect | $2.832 \times 10^{4}$ | cubic cins. |
| cubic fect | 1,728 | cubic inches. |
| cubic fect | 0.02832 | cubic meters. |
| cubic fect | 0.03704 | cubic yards. |
| cubic feet | 7.481 | gallons. |
| cubic feet | 28.32 | liters. |
| eubic feet | 59.84 | pints (liq.). |
| eubic feet | 29.92 | quarts (liq.). |
| eubic feet per minu | 472.0 | cubic cms. per see. |
| cubie feet per minute | 0.1247 | gallons per sec. |
| eubic feet per minute | 0.4720 | liters per second. |
| cubic feet per minute | 62.4 | lbs. of water per min. |
| cubic inches | 16.39 | cubic centimeters. |
| cubic inches | $5.787 \times 10^{-4}$ | cubic feet. |
| eubie inch | $1.639 \times 10^{-5}$ | cubic meters. |
| eubie inches | $2.143 \times 10^{-5}$ | cubic yards. |
| cubic inches | $4.329 \times 10^{-3}$ | gallons. |

Table 242.-Conversion Factors-Continued


Table 242. Conversion Factors-Continued

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| ergs | $1.020 \times 10^{-8}$ | kilogram-meters. |
| ergs per second | $5.692 \times 10^{-9}$ | B.t. units per minute. |
| crgs per sccond | $4.4 .26 \times 10^{-6}$ | foot-pounds per minute. |
| ergs per second | $7.376 \times 10^{-8}$ | foot-pounds per second. |
| crgs per sccond | $1.341 \times 10^{-10}$ | horse-power. |
| crgs por second | $1.434 \times 10^{-9}$ | kg.-calories per minute. |
| crgs per sccond. | $10^{-10}$ | kilowatts. |
| Fathoins | 6 | feet. |
| fcet | 30.48 | centimeters. |
| fect | 12 | inches. |
| feet | 0.3048 | meters. |
| fect | . 36 | varas. |
| fect | 1/3 | yards. |
| fect of water | 0.02950 | atmosphcres. |
| fect of water | 0.8826 | inches of mercury. |
| fect of water | 304.8 | kgs. per square meter. |
| fect of watc | 62.43 | pounds per sq. ft. |
| fect of wate | 0.4335 | pounds per sq. inch. |
| feet per minut | 0.5080 | centimeters per scc. |
| fect per minute | 0.01667 | fect per second. |
| fect per minute | 0.01829 | kilometcrs per hour. |
| fect per minute | 0.3048 | meters per minute. |
| fect per minute | 0.01136 | miles per hour. |
| fect per second | 30.48 | centimeters per sec. |
| fect per sccond | 1.097 | kilometers per hour. |
| fect per sccond | 0.5921 | knots per hour. |
| fcet per sccond | 18.29 | meters per minute. |
| feet per sccond | 0.6818 | miles per hour. |
| fect per second | 0.01136 | miles per minute. |
| feet per 100 fcct | 1 | per cont grade. |
| fcet per sec. per scc | 30.48 | cms. per sec. per sec. |
| feet per scc. per sec | 1.097 | kms. per hr. per sec. |
| feet per scc. per scc | 0.3048 | meters per sec. per scc. |
| fcet per sec. per sec | 0.6818 | milcs per hr. per sec. |
| foot-pounds. | $1.286 \times 10^{-3}$ | British thermal units. |
| foot-pounds. | $1.356 \times 10^{7}$ | ergs. |
| foot-pounds | $5.050 \times 10^{-7}$ | horse-power-hours. |
| foot-pounds | 1.356 | joules. |
| foot-pounds | $3.241 \times 10^{-4}$ | kilogram-calories. |
| foot-pounds | 0.1383 | kilogram-meters. |
| foot-pounds. | $3.766 \times 10^{-7}$ | kilowatt-hours. |
| foot-pounds per minute | $1.286 \times 10^{-3}$ | B.t. units per minute. |
| foot-pounds per minute | 0.01667 | foot-pounds per sec. |
| foot-pounds per minute. | $3.030 \times 10^{-5}$ | horse-power. |
| foot-pounds per minute. | $3.241 \times 10^{-4}$ | kg.-calorics per min. |
| foot-pounds per minute. | $2.260 \times 10^{-5}$ | kilowatts. |
| foot-pounds per second. | $7.717 \times 10^{-2}$ | B.t. units per minute. |
| foot-pounds per second | $1.818 \times 10^{-3}$ | horse-power. |
| foot-pounds per sccond. | $1.945 \times 10^{-2}$ | kg .-calories per min. |
| foot-pounds per second. | $1.356 \times 10^{-3}$ | kilowatts. |

Table 242. Conversion Factors-Continued

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| furlongs | 40 | rods. |
| Gallons. | 3785 | cubic centimeters. |
| gallons | 0.1337 | cubic feet. |
| gallons | 231 | cubic inches. |
| gallons | $3.785 \times 10^{-3}$ | cubic meters. |
| gallons. | $4.951 \times 10^{-3}$ | cubic yards. |
| gallons | 3.785 | liters. |
| gallons | 8 | pints (liq.). |
| gallons. | 4 | quarts (liq.). |
| gallons per minute | $2.228 \times 10^{-3}$ | cubic feet per second. |
| gallons per minute | 0.06308 | liters per second. |
| gills. | 0.1183 | liters. |
| gills | 0.25 | pints (liq.). |
| grains (troy) | 1 | grains (av.). |
| grains (troy) | 0.06480 | grams. |
| grains (troy) | 0.04167 | pennyweights (troy). |
| grams. | 980.7 | dynes. $\quad$. |
| grams | 15.43 | grains (troy). |
| grams | $10^{-3}$ | kilograms. |
| grams | $10^{3}$ | milligrams. |
| grams | 0.03527 | ounces. |
| grams | 0.03215 | ounces (troy). |
| grams | 0.07093 | poundals. |
| grams | $2.205 \times 10^{-3}$ | pounds. |
| gram-calories | $3.968 \times 10^{-3}$ | British thermal units. |
| gram-centimeters | $9.302 \times 10^{-3}$ | British thermal units. |
| gram-centimeters | 980.7 | ergs. |
| gram-centimeters | $7.233 \times 10^{-3}$ | foot-pounds. |
| gram-centimeters | $9.807 \times 10^{-5}$ | joules. |
| gram-centimeters | $2.344 \times 10^{-8}$ | kilogram-calories. |
| gram-centimeters | $10^{-5}$ | kilogram-meters. |
| grams per cm. | $5.600 \times 10^{-3}$ | pounds per inch. |
| grams per cu. cm | 62.43 | pounds per cubic foot. |
| grams per cu. cm | 0.03613 | pounds per cubic inch. |
| grams per cu. cm | $3.405 \times 10^{-7}$ | pounds per mil-foot. |
| Hectares | 2.471 | acres. |
| hectares | $1.076 \times 10^{5}$ | square feet. |
| hectograms | 100 | grams. |
| hectoliters | 100 | liters. |
| hectometers | 100 | meters. |
| hectowatts | 100 | watts. |
| hemispheres (sol. angle) | 0.5 | sphere. |
| hemispheres (sol. angle) | 4 | spherical right angles. |
| hemispheres (sol. angle) | 6.283 | steradians. |
| horse-power_- | 42.44 | B.t. units per min. |
| horse-power. | 33,000 | foot-pounds per min. |
| horse-power | 550 | foot-pounds per sec. |
| horse-power: | 1.014 | horse-power (metric). |
| horse-power | 10.70 | kg.-calories per min. |

Table 242. Conversion Factors-Continued

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| horse-power | 0.7457 | kilowatts. |
| horse-power | 745.7 | watts. |
| horse-power (boiler) | 33,520 | B.t.u. per hour. |
| horse-power (boiler) | 9.804 | kilowatts. |
| horse-power-hours | 2547 | British thermal units. |
| horse-power-hour | $1.98 \times 10^{6}$ | foot-pounds. |
| horse-power-hours | $2.684 \times 10^{6}$ | joules. |
| horse-power-hours | 641.7 | kilogram-calories. |
| horse-power-hours | $2.737 \times 10^{5}$ | kilogram-meters. |
| horse-power-hours | 0.7457 | kilowatt-hours. |
| hours | 60 | minutes. |
| hours | 3600 | seconds. |
| Inches | 2.540 | centimeters. |
| inches. | $10^{3}$ | mils. |
| inches | . 03 | varas. |
| inches of mercury | 0.03342 | atmospheres. |
| inches of mercur | 1.133 | feet of water. |
| inches of mercur | 345.3 | kgs. per square meter. |
| inches of mercury | 70.73 | pounds per square ft. |
| inches of mercury | 0.4912 | pounds per square in. |
| inches of water | 0.002458 | atmospheres. |
| inches of water | 0.07355 | inches of mercury. |
| inches of wate | 25.40 | kgs . per square meter. |
| inches of water | 0.5781 | ounces per square in. |
| inches of wate | 5.204 | pounds per square ft. |
| inches of water | 0.03613 | pounds per square in. |
| Joules. | $9.486 \times 10^{-4}$ | British thermal units. |
| joules | $10^{7}$ | ergs. |
| joules | 0.7376 | foot-pounds. |
| joules | $2.390 \times 10^{-4}$ | kilogram-calories. |
| joules | 0.1020 | kilogram-meters. |
| joules | $2.778 \times 10^{-4}$ | watt-hours. |
| Kilograms | 980,665 | dynes. |
| kilograms. | $10^{3}$ | grams. |
| kilograms | 70.93 | poundals. |
| kilograms. | 2.2046 | pounds. |
| kilograms. | $1.102 \times 10^{-3}$ | tons (short). |
| kilogram-calories | 3.968 | British thermal units. |
| kilogram-calories | 3088 | foot-pounds. |
| kilogram-calories | $1.588 \times 10^{-3}$ | horse-power-hours. |
| kilogram-calories | 4183 | joules. |
| kilogram-calories | 426.6 | kilogram-meters. |
| kilogram-calories | $1.162 \times 10^{-3}$ | kilowatt-hours. |
| kg -calories per min | 51.43 | foot-pounds per sec. |
| kg .-calories per min_ | 0.09351 | horse-power. |
| kg .-calories per min_ | 0.06972 | kilowatts. |
| $\mathrm{kgs} .-\mathrm{cms}$. squared_ | $2.373 \times 10^{-3}$ | pounds-feet squared. |
| kgs.-cms. squared | 0.3417 | pounds-inches squared. |

Table 242. Conversion Factors-Continued

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| kilogram-meters | $9.302 \times 10^{-3}$ | British thermal units. |
| kilogram-meters | $9.807 \times 10^{7}$ | ergs. |
| kilogram-meters | 7.233 | foot-pounds. |
| kilogram-meters | 9.807 | joules. |
| kilogram-meters | $2.344 \times 10^{-3}$ | kilogram-calories. |
| kilogram-meters | $2.724 \times 10^{-8}$ | kilowatt-hours. |
| kgs. per cubic mete | $10^{-3}$ | grams per cubic cm. |
| kgs. per cubic meter | 0.06243 | pounds per cubic foot. |
| kgs. per cubic meter | $3.613 \times 10^{-5}$ | pounds per cubic inch. |
| kgs. per cubic meter | $3.405 \times 10^{-10}$ | pounds per mil. foot. |
| kgs. per meter. | 0.6720 | pounds per foot. |
| kgs. per square meter | $9.678 \times 10^{-5}$ | atmospheres. |
| kgs. per square meter | 98.07 | bars. |
| kgs. per square meter | $3.281 \times 10^{-3}$ | feet of water. |
| kgs. per square meter | $2.896 \times 10^{-3}$ | inches of mercury. |
| kgs. per square meter | 0.2048 | pounds per square ft. |
| .kgs. per square meter | $1.422 \times 10^{-3}$ | pounds per square in. |
| kgs. per sq. millimeter | $10^{6}$ | kgs. per square meter. |
| kilolines_ | $10^{3}$ | maxwells. |
| kiloliters | $10^{3}$ | liters. |
| kilometers | $10^{5}$ | centimeters. |
| kilometers | 3281 | feet. |
| kilometers | $10^{3}$ | meters. |
| kilometers | 0.6214 | miles. |
| kilometers | 1093.6 | yards. |
| kilometers per hour | 27.78 | centimeters per sec. |
| kilometers per hour | 54.68 | feet per minute. |
| kilometers per hour | 0.9113 | feet per second. |
| kilometers per hour | 0.5396 | knots per hour. |
| kilometers per hour | 16.67 | meters per minute. |
| kilometers per hour | 0.6214 | miles per hour. |
| kms. per hour per sec | 27.78 | cms. per sec. per sec. |
| kms. per hour per sec | 0.9113 | ft . per sec. per sec. |
| kms. per hour per sec | 0.2778 | meters per sec. per sec. |
| kms. per hour per sec | 0.6214 | miles per hr. per sec. |
| kilometers per min | 60 | kilometers per hour. |
| kilowatts | $\dot{5} 6.92$ | B.t. units per min. |
| kilowatts | $4.425 \times 10^{4}$ | foot-pounds per min. |
| kilowatt | 737.6 | foot-pounds per sec. |
| kilowatt | 1.341 | horse-power. |
| kilowatt | 14.34 | kg.-calories per min. |
| kilowatt | $10^{3}$ | watts. |
| kilowatt-ho | 3415 | British thermal units. |
| kilowatt-hour | $2.655 \times 10^{6}$ | foot-pounds. |
| kilowatt-hour | 1.341 | horse-power-hours. |
| kilowatt-hours | $3.6 \times 10^{6}$ | joules. |
| kilowatt-hour | 860.5 | kilogram-calories. |
| kilowatt-hours | $3.671 \times 10^{5}$ | kilogram-meters. |
| knots | 51.48 | centimeters per sec. |
| knots | 1.689 | feet per second. |
| knots | 1.853 | kilometers per hour. |

Tahle 242. Conversion Factors-Coutinned

| Multiply | by | to obtan |
| :---: | :---: | :---: |
| knots | 1.152 | miles per hour. |
| Links (engineer's). | 12 | inches. |
| links (surveyor's). | 7.92 | inches. |
| liters.- | $10^{3}$ | cubic centimeters. |
| liters | 0.03531 | cubic feet. |
| liters | 61.02 | cubic inches. |
| liters | $10^{-3}$ | cubic meters. |
| liters. | $1.308 \times 10^{-3}$ | cubic yards. |
| liters | 0.2642 | gallons. |
| liters | 2.113 | pints (lic.). |
| liters | 1.057 | quarts (liq.). |
| liters per minute | $5.885 \times 10^{-4}$ | cubic feet per second. |
| liters per minute. | $4.403 \times 10^{-3}$ | gallons per second. |
| $\log _{10} N$.-- | 2.303 | $\log \epsilon N$ or $\ln N$. |
| $\log \epsilon N$ or $\ln N_{-}$ | 0.4343 | $\log _{10} N$. |
| lumens per sq. ft | 1 | foot-caridles. |
| Meters | 100 | centimeters. |
| meter | 3.2808 | feet. |
| meters | 39.37 | inches. |
| meters | $10^{-3}$ | kilometers. |
| meters | $10^{3}$ | millimeters. |
| meter | 1.0936 | yards. |
| meter-kilograms. | $9.807 \times 10^{7}$ | centimeter-dynes. |
| meter-kilograms | $10^{5}$ | centimeter-grams. |
| meter-kilograms. | 7.233 | pound-fect. |
| meters per minute | 1.667 | centimeters per sec. |
| meters per minute | 3.281 | feet per minute. |
| meters per minute | 0.05468 | feet per second. |
| meters per minute | 0.06 | kilometers per hour. |
| meters per minute | 0.03728 | miles per hour. |
| meters per second | 196.8 | feet per minute. |
| meters per second. | 3.281 | feet per second. |
| meters per second | 3.6 | kilometers per hour. |
| meters per second | 0.06 | kilometers per min. |
| meters per second. | 2.237 , | miles per hour. |
| meters per second. | 0.03728 | miles per minute. |
| meters per sec. per se | 3.281 | feet per sec. per sec. |
| meters per sec. per se | 3.6 | kms. per hour per sec. |
| meters per sec. per se | 2.237 | miles per hour per sec. |
| microns | $10^{-6}$ | meters. |
| miles | $1.609 \times 10^{5}$ | centimeters. |
| miles | 5280 | feet. |
| miles | 1.6093 | kilometers. |
| miles | 1760 | yards. |
| miles | 1900.8 | varas. |
| miles per hour | 44.70 | centimeters per sec. |
| miles per hour | 88 | feet per minute. |
| miles per hour | 1.467 | feet per second. |
| miles per hour | 1.6093 | kilometers per hour. |

Table 242: Conversion Factors-Continued

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| miles per hour | 0.8684 | knots per hour. |
| miles per hour | 26.82 | meters per minute. |
| miles per hour per sec | 44.70 | cms. per sec. per sec. |
| miles per hour per sec | 1.467 | feet per sec. per sec. |
| miles per hour per sec | 1.6093 | kms. per hour per sec. |
| miles per hour per sec | 0.4470 | M. per sec. per sec. |
| miles per minute | 2682 | centimeters per sec. |
| miles per minute | 88 | feet per second. |
| miles per minute | 1.6093 | kilometers per min. |
| miles per minute | 0.8684 | knots per minute. |
| miles per minute | 60 | miles per hour. |
| milliers | $10^{3}$ | kilograms. |
| milligrams | $10^{-3}$ | grams. |
| milliliters | $10^{-3}$ | liters. |
| millimeters | 0.1 | centimeters. |
| millimeters | 0.03937 | inches. |
| millimeters | 39.37 | mils. |
| mils. | 0.002540 | centimeters. |
| mils. | $10^{-3}$ | inches. |
| miner's inches | 1.5 | cubic feet per min. |
| minutes (angle) | $2.909 \times 10^{-4}$ | radians. |
| minutes (angle) | 60 | seconds (angle). |
| months | 30.42 | days. |
| months | 730 | hours. |
| months. | 43,800 | minutes. |
| months | $2.628 \times 10^{8}$ | seconds. |
| myriagrams | 10 | kilograms. |
| myriameters | 10 | kilometers. |
| myriawatts | 10 | kilowatts. |
| Nautical miles | 6080 | feet. |
| nautical miles | 1.853 | kilometers. |
| nautical miles | 1.152 | miles. |
| nautical miles | 2027 | yards. |
| Ounces_ | 8 | drams. |
| ounces | 437.5 | grains. |
| ounces | 28.35 | grams. |
| ounces. | 0.0625 | pounds. |
| ounces (fluid) | 1.805 | cubic inches. |
| ounces (fluid) | 0.02957 | liters. |
| ounces (troy) | 480 | grains (troy). |
| ounces (troy) | 31.10 | grams. |
| ounces (troy) | 20 | pennyweights (troy). |
| ounces (troy) | 0.08333 | pounds (troy). |
| ounces per square inch | 0.0625 | pounds per sq. inch. |
| Pennyweights (troy) | 24 | grains (troy). |
| pennyweights (troy) | 1.555 | grams. |
| pennyweights (troy) | 0.05 | ounces (troy). |
| pcrches (masonry).- | 24.75 | cubic feet. |

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Table.242. Conversion Factors-Continued

| Multiply | by | to obtain |
| :---: | :---: | :---: |
| pints (dry) | 33.60 | cubic inches. |
| pints (liq.) | 28.87 | cubic inches. |
| poundals. | 13,826 | dynes. |
| poundals. | 14.10 | grams. |
| poundals | 0.03108 | pounds. |
| pounds. | 444,823 | dynes. |
| pounds | 7000 | grains. |
| pounds. | 453.6 | grams. |
| pounds. | 16 | ounces. |
| pounds. | 32.17 | poundals. |
| pounds (troy) | 0.8229 | pounds (av.). |
| pound-feet. | $1.356 \times 10^{7}$ | centimeter-dynes. |
| pound-feet | 13,825 | centimeter-grams. |
| pound-feet | 0.1383 | meter-kilograms. |
| pound-feet squared. | 421.3 | kgs.-cms. squared. |
| pounds-feet squared. | 144 | pounds-ins. squared. |
| pounds-inches squared | 2.926 | kgs.-cms. squared. |
| pounds-inches squared | $6.945 \times 10^{-3}$ | pounds-feet squared. |
| pounds of water | 0.01602 | cubic feet. |
| pounds of water | 27.68 | cubic inches. |
| pounds of water | 0.1198 | gallons. |
| pounds of water per min | $2.669 \times 10^{-4}$ | cubic feet per sec. |
| pounds per cubic foot. | 0.01602 | grams per cubic cm. |
| pounds per cubic foot. | 16.02 | kgs. per cubic meter. |
| pounds per cubic foot. | $5.787 \times 10^{-4}$ | pounds per cubic inch. |
| pounds per cubic foot. | $5.456 \times 10^{-9}$ | pounds per mil foot. |
| pounds per cubic inch | 27.68 | pounds per cubic cm. |
| pounds per cubic inch | $2.768 \times 10^{4}$ | kgs . per cubic meter. |
| pounds per cubic inch | 1728 | pounds per cubic foot. |
| pounds per cubic inch | $9.425 \times 10^{-6}$ | pounds per mil foot. |
| pounds per foot. | 1.488 | kgs . per meter. |
| pounds per inch. | 178.6 | grams per cm. |
| pounds per mil foot | $2.306 \times 10^{6}$ | grams per cubic cm. |
| pounds per square foot | 0.01602 | feet of water. |
| pounds per square foot-_ | 4.882 | kgs. per square meter. |
| pounds per square foot. | $6.944 \times 10^{-3}$ | pounds per sq. inch. |
| pounds per square inch. | 0.06804 | atmospheres. |
| pounds per square inch | 2.307 | feet of water. |
| pounds per square inch. | 2.036 | inches of mercury. |
| pounds per square inch. | 703.1 | kgs. per square meter. |
| pounds per square inch | 144 | pounds per sq. foot. |
| Quadrants (angle) | 90 | degrees. |
| quadrants (angle) | 5400 | minutes. |
| quadrants (angle) | 1.571 | radians. |
| quarts (dry) | 67.20 | cubic inches. |
| quarts (liq.) | 57.75 | cubic inches. |
| quintals | 100 | pounds. |
| quires----- | 25 | sheets. |
| Radians | 57.30 | degrees. |
| radians | 3438 | minutes. |

Table 242.: Conversion Factors-Continued

| Multiply | by . | to obtain |
| :---: | :---: | :---: |
| radians | 0.637 | quadrants. |
| radians per second | 57.30 | degrees per second. |
| radians per second | 0.1592 | revolutions per sec. |
| radians per second | 9.549 | revolutions per min. |
| radians per sec. per se | 573.0 | revs. per min. per min. |
| radians per sec. per sec | 9.549 | revs. per min. per sec. |
| radians per sec. per se | 0.1592 | revs. per sec. per sec. |
| reams | 500 | sheets. |
| revolution | 360 | degrees. |
| revolutions | 4 | quadrants. |
| revolutions | 6.283 | radians. |
| revolutions per minut | 6 | degrces per second. |
| revolutions per minute | 0.1047 | radians per second. |
| revolutions per minute | 0.01667 | revolutions per sec. |
| revs. per min. per min | $1.745 \times 10^{-3}$ | rads. per sec. per sec. |
| revs. per min. per min | . 0.01667 | revs. per min. per sec. |
| revs. per min. per min | $2.778 \times 10^{-4}$ | revs. per sec. per sec. |
| revolutions per second | - 360 | degrees per second. |
| revolutions per second | 6.283 | radians per second. |
| revolutions per second | 60 | revs. per minute. |
| revs. per sec. per sec. | 6.283 | rads. per sec. per sec. |
| revs. per sec. per sec | 3600 | revs. per min. per min. |
| revs. per sec. per se | 60 | revs. per min. per sec. |
| rods | 16.5 | feet. |
| Seconds (angle) | $4.848 \times 10^{-8}$ | radians. |
| spheres (solid angle) | 12.57 | steradians. |
| spherical right angles. | 0.25 | hemispheres. |
| spherical right angles | 0.125 | spheres. |
| spherical right angles. | 1.571 | steradians. |
| square centimeters | $1.973 \times 10^{5}$ | circular mils. |
| square centimeters | $1.076 \times 10^{-3}$ | square feet. |
| square centimeter: | 0.1550 | square inches. |
| square centimeter | $10^{-6}$ | square meters. |
| square centimeters | 100 | square millimeters. |
| square feet | $2.296 \times 10^{-5}$ | acres. |
| square feet | 929.0 | square centimeters. |
| square feet | 144 | square inches. |
| square feet | 0.09290 | square meters. |
| square feet. | $3.587 \times 10^{-8}$ | square miles. |
| square feet. | .1296 | square varas. |
| square feet | 1/9 | square yards. |
| sq. feet-feet sqd | $2.074 \times 10^{4}$ | sq. inches-inches sqd. |
| square inches. | $1.273 \times 10^{6}$ | circular mils. |
| square inches. | 6.452 | square centimeters. |
| square inches. | $6.944 \times 10^{-3}$ | square feet. |
| square inches. | $10^{8}$ | square mils. |
| square inches | 645.2 | square millimeters. |
| sq. inches-inches sqd | 41.62 | sq. cms.-cms. sqd. |
| sq. inches-inches sqd | $4.823 \times 10^{-5}$ | sq. feet-feet sqd. |
| square kilometers.- | 247.1 | acres. |

Table 242. Conversion Factors-Continued

| Multiply | hy | to obtain |
| :---: | :---: | :---: |
| square kilometers. | $10.76 \times 10^{6}$ | square feet. |
| square kilometers | $10^{8}$ | square meters. |
| square kilometers. | 0.3861 | square miles. |
| square kilometers. | $1.196 \times 10^{6}$ | square yards. |
| square meters | $2.471 \times 10^{-4}$ | .aeres. |
| square meters | 10.764 | square feet. |
| square meters. | $3.861 \times 10^{-7}$ | square miles. |
| square meters. | 1.196 | square yards. |
| square miles | 640 | acres. |
| square miles | $27.88 \times 10^{6}$ | square feet. |
| square miles | 2.590 | square kilometers. |
| square miles | 3.613,040.45 | square varas. |
| square miles | $3.098 \times 10^{6}$ | square yards. |
| square millimeters. | $1.973 \times 10^{3}$ | eireular mils. |
| square millimeters. | 0.01 | square eentimeters. |
| square millimeters. | 1. $550 \times 10^{-3}$ | square inches. |
| square mils. | 1.273 | eireular mils. |
| square mils. | $6.452 \times 10^{-6}$ | square centimeters. |
| square mils | $10^{-6}$ | square inches. |
| square varas | . 0001771 | acres. |
| square varas | 7.716049 | square feet. |
| square varas | . 0000002765 | square miles. |
| square varas | . 857339 | square yards. |
| square yards | $2.066 \times 10^{-4}$ | aeres. |
| square yards | 9 | square feet. |
| square yards | 0.8361 | square meters. |
| square yards | $3.228 \times 10^{-7}$ | square miles. |
| square yards | 1.1664 | square varas. |
| steradians | 0.1592 | hemispheres. |
| steradia | 0.07958 | spheres. |
| steradian | 0.6366 | spherieal right angles. |
| steres | $10^{3}$ | liters. |
| Temp. (degs. C.) +273 | 1 | abs. temp. (degs. C.). |
| temp. (degs. C.) +17.8 | 1.8 | temp. (degs. Fahr.). |
| temp. (degs. F.) +460 | 1 | albs. temp. (degs. F.). |
| temp. (degs. F.) - 32 | 5/9 | temp. (degs. Cent.). |
| tous (long) | 1016 | kilograms. |
| tons (long) | 2240 | pounds. |
| tons (metrie) | $10^{3}$ | kilograms. |
| tons (metric) | 2205 | pounds. |
| tons (short) | 907.2 | kilograms. |
| tons (short) | 2000 | pounds. |
| tons (short) per sq. ft | 9765 | kgs . per square meter. |
| tons (short) per sq. ft | 13.89 | pounds per sq. ineh. |
| tons (short) per sq. in. | $1.406 \times 10^{6}$ | kgs . per square meter. |
| tons (short) per sq. in. | 2000 | pounds per sq. inch. |
| Varas | 2.7777 | feet. |
| varas.- | 33.3333 | inches. |
| varas.-.-- | . 000526 | miles. |

Table 242. Conversion Factors-Continued

| Multiply | by | to öbtain |
| :---: | :---: | :---: |
| varas | . 9259 | yards. |
| Watts_ | - 0.05692 | B.t. units per min. |
| watts | $10^{7}$ | ergs per second. |
| watts | - 44.26 | foot-pounds per min. |
| watts | 0.7376 | foot-pounds per sec. |
| watts | $1.341 \times 10^{-3}$ | horse-power. |
| watts | 0.01434 | kg.-calories per min. |
| watts | - $10{ }^{2}$ | kilowatts. |
| watt-hours_ | 3.415 | British thermal units. |
| watt-hours. | 2655 | foot-pounds. |
| watt-hours. | $1.341 \times 10^{-3}$ | horse-power-hours. |
| watt-hours. | 0.8605 | kilogram-calories. |
| watt-hours. | 367.1 | kilogram-meters. |
| watt-hours. | $10^{-3}$ | kilowatt-hours. |
| webers | $10^{8}$ | maxwells. |
| weeks | 168 | hours. |
| weeks | 10,080 | minutes. |
| weeks | 604,800 | seconds. |
| Yards | 91.44 | centimeters. |
| yards | 3 | feet. |
| yards | 36 | inches. |
| yards | 0.9144 | meters. |
| yards | 1.08 | varas. |
| years (common) | 365 | days. |
| years (common) | 8760 | hours. |
| years (leap) | 366 | days. |
| years (leap) | 8784 | hours. |

## 225. Twenty-Year Calendar

The calendar for each month from 1956 to 1975 is shown in figure 111.

|  | $\left.\begin{gathered} \mathrm{JAN} \\ 3 \mathrm{I} \\ \text { DAYS } \end{gathered} \right\rvert\,$ | $\begin{gathered} \text { FEB } \\ 28 \\ \text { DAYS } \end{gathered}$ | MAR 31 DAYS | APR 30 <br> DAYS | MAY 31 DAYS | $\begin{gathered} \text { JUNE } \\ 30 \\ \text { DAYS } \end{gathered}$ | JU LY 31 <br> DAYS | AUG 31 DAYS | $\begin{gathered} \text { SEPT } \\ 30 \\ \text { DAYS } \end{gathered}$ |  | NOV 30 <br> DAYS | DEC 31 DAYS |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1956 | A | D* | E | A | C | - F | A | D | G | B | E | G |
| 1957 | C | F | F | B | D | G | B | E | A | C | F | A |
| 1958 | D | G | G | C | E | A | C | F | B | D | G | B |
| 1959 | E | A | A | D | F | B | D | G | C | E | A | C |
| 1960 | F | B* | C | F | A | D | F | B | E | G | C | E |
| 1961 | A | D | D | G | B | E | C | C | F | A | D | ${ }^{1} \mathrm{~F}$ |
| 1962 | B | E | E | A | C | F | A | D | G | B | E | G |
| 1963 | C | F | F | B | D | G | B | E | A | C | F | A |
| 1964 | D | $\mathrm{G}^{*}$ | A | D | F | B | D | G | C | E | A | C |
| 1965 | F | B | B | E | G | C | F | A | D | F | B | D |
| 1966 | G | C | C | F | A | D | F | B | E | G | C | E |
| 1967 | A | D | D | G | B | E | G | C | F | A | D | F |
| 1968 | B | E* | F | B | D | G | B | E | A | C | F | A |
| 1969 | D | G | G | C | E | A | C | F | B | D | G | B |
| 1970 | E | A | A | D | F | B | D | G | C | E | A | C |
| 1971 | F | B | B | E | G | C | E | A | D | F | B | D |
| 1972 | G | C | D | G | B | E | G | C | F | A | D | F |
| 1973 | B | E | E | A | C | F. | A | D | G | B | E | G |
| 1974 | C | F | F | B | D | G | B | E | A | C | F | A |
| 1975 | D | G | G | C | E | A | C | F | B | D | G | B |

* LEAP YEARS FEBRUARY HAS 29 DAYS

|  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | M | T | w |  |  |  |
|  | 2 | 3 | 4 | 5 | 6 |  |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|  | 30 | 31 |  |  |  |  |


| CALENDAR |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| $\mathbf{S}$ | M | T | W | T | F | S |
| 7 | 1 | 2 | 3 | 4 | 5 | 6 |
| 14 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 16 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | 31 |  |  |  |


|  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| s | M |  | w |  | F |  |
|  |  | 1 | 2 | 3 | 4 |  |
|  | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|  | 28 | 29 | 30 |  |  |  |


| Calendar ( ${ }^{\text {d }}$ |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | M | T | w | T |  |  |
|  |  |  | 1 | 2 |  |  |
|  | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 |  |


| E |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | M | T |  | T |  |  |
|  |  |  |  | 1 | 2 |  |
|  | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 |  |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |


| CALENDAR F |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 5 | M | T | W | T | F | S |
|  |  |  |  |  | 1 | 2 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 |  |  |  |  |  |  |


| CALENDAR |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: |
| S | M | T | W | T | F |
| 2 | 3 | S |  |  |  |
| 2 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 |
| 16 | 17 |  |  |  |  |
| 23 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 |
| 30 | 31 | 29 |  |  |  |

Figure 111. Twenty-year calendar.

## 226. Table of Days Between Two Dates

Table 243 shows the elapsed time in days between two dates, inclusive of both the initial and the terminal date.

Note. For a leap year add one day after 28 February.
Table 243. Elapsed Days

| Day | Month |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Jan. | Feb. | Mar. | Apr. | May | Junc | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|  | 1 | 32 | 60 | 91 | 121 | 152 | 182 | 213 | 244 | 274 | 305 | 335 |
| 2 | 2 | 33 | 61 | 92 | 122 | 153 | 183 | 214 | 245 | 275 | 306 | 336 |
| 3 | 3 | 34 | 62 | 93 | 123 | 154 | 184 | 215 | 246 | 276 | 307 | 337 |
| 4 | 4 | 35 | 63 | 94 | 124 | 155 | 185 | 216 | 247 | 277 | 308 | 338 |
| 5 | 5 | 36 | 64 | 95 | 125 | 156 | 186 | 217 | 248 | 278 | 309 | 339 |
| 6 | 6 | 37 | 65 | 96 | 126 | 157 | 187 | 218 | 249 | 279 | 310 | 340 |
| 7. | 7 | 38 | 66 | 97 | 127 | 158 | 188 | 219 | 250 | 280 | 311 | 341 |
| 8. | 8 | 39 | 67 | 98 | 128 | 159 | 189 | 220 | 251 | 281 | 312 | 342 |
| 9 | 9 | 40 | 68 | 99 | 129 | 160 | 190 | 221 | 252 | 282 | 313 | 343 |
| 10. | 10 | 41 | 69 | 100 | 130 | 161 | 191 | 222 | 253 | 283 | 314 | 344 |
| 11. | 11 | 42 | 70 | 101 | 131 | 162 | 192 | 223 | 254 | 284 | 315 | 345 |
| 12 | 12 | 43 | 71 | 102 | 132 | 163 | 193 | 224 | 255 | 285 | 316 | 346 |
| 13 | 13 | 44 | 72 | 103 | 133 | 164 | 194 | 225 | 256 | 286 | 317 | 347 |
| 14 | 14 | 45 | 73 | 104 | 134 | 165 | 195 | 226 | 257 | 287 | 318 | 348 |
| 15. | 15 | 46 | 74 | 105 | 135 | 166 | 196 | 227 | 258 | 288 | 319 | 349 |
| 16 | 16 | 47 | 75 | 106 | 136 | 167 | 197 | 228 | 259 | 289 | 320 | 350 |
| 17 | 17 | 48 | 76 | 107 | 137 | 168 | 198 | 229 | 260 | 290 | 321 | 351 |
| 18 | 18 | 49 | 77 | 108 | 138 | 169 | 199 | 230 | 261 | 291 | 322 | 352 |
| 19 | 19 | 50 | 78 | 109 | 139 | 170 | 200 | 231 | 262 | 292 | 323 | 353 |
| 20 | 20 | 51 | 79 | 110 | 140 | 171 | 201 | 232 | 263 | 293 | 324 | 354 |
| 21 | 21 | 52 | 80 | 111 | 141 | 172 | 202 | 233 | 264 | 294 | 325 | 355 |
| 22 | 22 | 53 | 81 | 112 | 142 | 173 | 203 | 234 | 265 | 295 | 326 | 356 |
| 23 | 23 | 54 | 82 | 113 | 143 | 174 | 204 | 235 | 266 | 296 | 327 | 357 |
| 24. | 24 | 55 | 83 | 114 | 144 | 175 | 205 | 236 | 267 | 297 | 328 | 358 |
| 25 | 25 | 56 | 84 | 115 | 145 | 176 | 206 | 237 | 268 | 298 | 329 | 359 |
| 26 | 26 | 57 | 85 | 116 | 146 | 177 | 207 | 238 | 269 | 299 | 330 | 360 |
| 27 | 27 | 58 | 86 | 117 | 147 | 178 | 208 | 239 | 270 | 300 | 331 | 361 |
| 28 | 28 | 59 | 87 | 118 | 148 | 179 | 209 | 240 | 271 | 301 | 332 | 362 |
| 29 | 29 |  | 88 | 119 | 149 | 180 | 210 | 241 | 272 | 302 | 333 | 363 |
| 30 | 30 |  | 89 | 120 | 150 | 181 | 211 | 242 | 273 | 303 | 334 | 364 |
| 31. | 31 |  | 90 |  | 151 | --- | 212 | 243 | --- | 304 |  | 365 |

Table.249. Elapsed Days-Continued

| Day | Month |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nor. | Dec. |
|  | 366 | 397 | 425 | 456 | 486 | 517. | 547 | 578 | 609 | 639 | 670 | 700 |
|  | 367 | 398 | 426 | 457 | 487 | 518 | 548 | 579 | 610 | 640 | 671 | 701 |
|  | 368 | 399 | 427 . | 458 | 488 | 519 | 549 | 580 | 611 | 641 | 672 | 702 |
|  | 369 | 400 | 428 | 459 | 489 | 520 | 550 | 581 | 612 | 642 | 673 | 703 |
|  | 370 | 401 | 429 | 460 | 490 | 521 | 551 | 582 | 613 | 643 | 674 | 704 |
|  | 371 | 402 | 430. | 461 | 491 | 522 | 552 | 583 | 614 | 644 | 675 | 705 |
|  | 372 | 403 | 431 | 462 | 492 | 523 | 553 | 584 | 615 | 645 | 676 | 706 |
|  | 373 | 404 | 432 | 463 | 493 | 524 | 554 | 585 | 616 | 646 | 677 | 707 |
|  | 374 | 405 | 433 | 464 | 494 | 525 | 555 | 586 | 617 | 647 | 678 | 708 |
| 10 | 375 | 406 | . 434 | 465 | 495 | 526 | 556 | 587 | 618 | 648 | 679 | 709 |
|  | 376 | 407 | 435 | 466 | 496 | 527 | 557 | 588 | 619 | 649 | 680 | 710 |
| 12 | 377 | 408 | 436 | 467 | 497 | 528 | 558 | 589 | 620 | 650 | 681 | 711 |
| 13 | 378 | 409 | 437 | 468 | 498 | 529 | 559 | 590 | 621 | 651 | 682 | 712 |
| 14 | 379 | 410 | 438 | 469 | 499 | 530 | 560 | 591 | 622 | 652 | 683 | 713 |
| 15 | 380 | 411 | 439 | 470 | 500 | 531 | 561 | 592 | 623 | 653 | 684 | 714 |
| 16 | 381 | 412 | 440 | 471 | 501 | 532 | 562 | 593 | 624 | 654 | 685 | 715 |
| 17 | 382 | 413 | 441 | 472 | 502 | 533 | 563 | 594 | 625 | 655 | 686 | 716 |
| 18. | 383 | 414 | 442 | 473 | 503 | 534 | 564 | 595 | 626 | 656 | 687 | 717 |
| 19. | 384 | 415 | 443 | 474 | 504 | 535 | 565 | 596 | 627 | 657 | 688 | 718 |
| 20. | 385 | 416 | 444 | 475 | 505 | 536 | 566 | 597 | 628 | 658 | 689 | 719 |
| 21. | 386 | 417 | 445 | 476 | 506 | 537 | 567 | 598 | 629 | 659 | 690 | 720 |
| 22 | 387 | 418 | 446 | 477 | 507 | 538 | 568 | 599 | 630 | 660 | 691 | 721 |
| 23 | 388 | 419 | 447 | 478 | 508 | 539 | 569 | 600 | 631 | 661 | 692 | 722 |
| 24 | 389 | 420 | 448 | 479 | 509 | 540 | 570 | 601 | 632 | 662 | 693 | 723 |
| 25 | 390 | 421 | 449 | 480 | 510 | 541 | 571 | 602 | 633 | 663 | 694 | 724 |
| 26. | 391 | 422 | 450 | 481 | 511 | 542 | 572 | 603 | 634 | 664 | - 695 | 725 |
| 27 | 392 | 423 | 451 | 482 | 512 | 543 | 573 | 604 | 635 | 665 | 696 | 726 |
| 28 | 393 | 424 | 452 | 483 | 513 | 544 | 574 | 605 | 636 | 667 | 697 | 727 |
| 29--- | 394 |  | 453 | 484 | 514 | 545 | 575 | 606 | 637 | 666 | 698 | 728 |
| 30 | 395 |  | 454 | 485 | 515 | 546 | 576 | 607 | 638 | 668 | 699 | 729 |
| 31 | 396 |  | 455 |  | 516 |  | 577 | 608 |  | 669 |  | 730 |

## 227. Hours of Daylight

Table 244. Hours of Daylight ${ }^{1}$

| Latitude north ${ }^{2}$ | Month |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
| $0^{\circ}$ | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| $10^{\circ}$ | 12 | 12 | 12 | 12 | 13 | 13 | 13 | 12 | 12 | 12 | 12 | 12 |
| $20^{\circ}$ | 11 | 12 | 12 | 13 | 13 | 13 | 13 | 13 | 12 | 12 | 11 | 11 |
| $30^{\circ}$ | 10 | 11 | 12 | 13 | 14 | 14 | 14 | 13 | 12 | 11 | 11 | 10 |
| $40^{\circ}$ | 10 | 11 | 12 | 13 | 14 | 15 | 15 | 14 | 12 | 11 | 10 | 9 |
| $50^{\circ}$ | 9 | 10 | 12 | 14 | 15 | 16 | 16 | 14 | 12 | 11 | 9 | 8 |
| $60^{\circ}$ | 7 | 9 | 12 | 15 | 17 | 19 | 18 | 16 | 12 | 10 | 8 | 6 |
| $70^{\circ}$ | 0 | 7 | . 12 | 16 | 23 | 24 | 24 | 18 | 12 | 9 | 4 | 0 |
| $80^{\circ}$ | 0 | 0 | 12 | 24 | 24 | 24 | 24 | 24 | 12 | 5 | 0 | 0 |

${ }^{1}$ Time between sunrise and sunset. Approximately 30 minutes twilight is avallable before sunrise and after sunset.
${ }^{2}$ For latitude south, subtract figure given from 24.

## 228. Library Reference Sets for Engineer Units

Library reference sets for engineering units are listed below. Reference works are grouped by sets in table 245.

Set
No.

## Description

1 Celestial Navigation
2 Company
3 Heavy Shop Company
4 Maintenance Company
5 Regiment
6 Road Construction
7 Topographic Battalion, Headquarters and Service Company, Army
8 Topographic Battalion, Headquarters and Service Company, General Headquarters.
9 Topographic Battalion, Photomapping Company
10 Topographic Battalion, Reproduction Company
11 Topographic Battalion, Survey Company
12 Topographic Company, Aviation
13 Topographic Company, Corps
14 Water Supply Company
15 Forestry Operations
Table 245. Reference Works, Grouped by Subjects

| Reference works | In library reference sets Nos. |
| :---: | :---: |
| Engineer's Handbooks: |  |
| American Electricians' Handbook-Croft | 3-5-7-8-9-12-13 |
| Civil Engineers' Reference Book-Trautwine | 2-5-15 |
| Mechanical Engineer's Handbook-Marks. | 5-7-8-9 |
| Mathematics and Science: |  |
| Trigonometry-Kells, Kerns and Bland. | 8-9-12 |
| Calculus, Differential and Integral-Granville | 8 |

Table.245. Reference Worles, Grouped by Subjects—Continued

| .Reference works | In library reference sets Nos. |
| :---: | :---: |
| Mathematics and Science-Continued |  |
| Errors and Theory of Least Squarcs-Welds | 8 |
| Chemistry and Physics Handbook-Hodgman | 7-10-12-14 |
| Chemical Engineers' Handbook-Perry . | 14 |
| Medicinc, Military Preventive-Col Dunha | 14 |
| Tables, Cube and Square Roots-Barlow | 7 |
| Tables of Functions of Angles-Vega | 7-8-9-11-12-13 |
| Tables of Functions of Angles-Ives_ | 7-8-9-11-12-13 |
| Construction: $\cdot$ |  |
| Standard Construction Methods-Underwood | 2 |
| Building Construction Handbook ( 2 Vol )-Hool and Johnson. | 5 |
| Steel Construction Handbook-American Inst. of Steel Construction. | 5 |
| Asphalt Highway, Engineers' Pocket Reference Book- | 6 |
| Concrete Inspection Manual-American Concrete Inst. | 6 |
| Concrete Mixtures, Design and Control-Portland Cement Association. | 6 |
| Asphalt Construction Specifications-Asphalt Inst | 6 |
| Highway Engineers' Handbook-Harger and Bonney, Vol. 1. | 5 |
| Highway Design and Construction-Bruce_ | 6 |
| Military Roads in Forward Areas Occasional Papers No. 74, Nov. 41-The Engineer School. | 6 |
| Soil Cement Roads-Portland Cement Association | 6 |
| Soil Mechanics and Stabilization, Vol. 18, part 2, Highway Research Board, Washington. | 6 |
| Soil stabilization w/Asphalt Bulletin_ | 6 |
| Forestry |  |
| Logging-Bryant | 15 |
| Lumber, Its Manufacture and Distribution-Bryant, | 15 |
| Pub. No. 509, Operating Small Sawmills-U.S. Dept. of Agriculture. | 15 |
| Maintenance and Repairs: |  |
| Are Welding Instruction Course, Exercises. | 3-4 |
| Arc Welding Instruction Courses, Lectures-Air Reduction Sales Co. | 3-4 |
| Automotive Construction and Repair Manual-F. L. Curfman Mfg. Co. | 3 |
| Drilling and Surfacing Practice-Colvin and Stanley | 3 |
| Gear Cutting Practice-Colvin and Stanley | 3 |
| Machine Shop Technology, 6 parts-National Metal Trades Association. | 3-4 |
| Machine Shop Training Course, 2 Vol.-Franklin and Jones. | 3 |
| Machine Tools and Their Operation, 2 Parts-Colvin and Stanley. | 3 |
| American Machinists' Handbook-Colvin and Stanley.- | 3 |


| Reference works | In library reference sets Nos. |
| :---: | :---: |
| Maintenance and Repairs-Continued |  |
| Oxyacetylene Handbook, Revised-Linde Air Production Co. | 3 |
| Turning and Boring Practice-Colvin and Stanley | 3 |
| Welding and Cutting (Oxyacetylene) Lectures | 3-4 |
| Welding and Cutting (Oxyacetylene) Work Sheets-Air Reduction Sales Co. | 3-4 |
| Welding and Its Application-Rossi | 3-4 |
| Welding Design and Practice, Procedure-Lincoln Elec. Co. | 3-4 |
| Welding Encyclopedia-MacKenzie and H. S. Card_-.-- | 3 |
| Surveying and Mapping: |  |
| Almanac, American Air-Naval Observatory | 1 |
| Almanac, Nautical, and Ephemeris-Naval Observatory | 1-7-8-12-13 |
| Navigation and Nautical Astronomy-Dutton | 1-7-8-13 |
| Radio Time Signals-H.O. 205 Extract. | 1 |
| American Practical Navigator-USN H.O. No. | 1 |
| Computer, Polaris, Azimuth and Altitude-USGS Polastroidal Jr. | 1-7-8-11-12 |
| Aero Photography and Aero Surveying-Bagley .-. -- -- | 7-12 |
| Astronomy, Field-Hosmer | 7-8-12 |
| Geodesy-Ingram. | 7-8 |
| Geodesy-Hosmer | 8 |
| Grid System for Military Maps-Engr Repro Plant | 8-9-10-12-13 |
| Photogrammetry-Anderson | 7 |
| Photogrammetry, Aerial and Terrestrial-Talley_....... | 7-8-9-12-13 |
| Photogrammetry, Manual of-Amer Soc of Photographers. | 7-9-12-13 |
| Photography, Elementary-Neblette, Brehm and Priest.- | 7-10-12-13 |
| Photography, Theory and Practice of-Clerc---------- | 7-12 |
| Surveying, Vol. I-Breed and Hosmer-.-.-.-.-........- | 7-13-15 |
|  | 7-13 |
| Surveying-Tracey | 13 |
| Surveying Computations-HMSO_ | 7 |
| Pub. No. 43, Metric Computations of Position-USC and GS. | 7-8-9-12 |
| Tables, Manuals, Bulletins-USC and GS--------------1-1 | 7-8-9-11-12-13 |
|  | 10-12 |
| Lithographers Manual-Soderstorm | 10-12 |
| Printing, Practice of - Polk_ | 12 |
| Albumen Photolithography - Litho Tech Fnd | 12 |
| Photolithography-Sayre.- | 12-13 |
| Water Supply: |  |
|  | 14 |
|  | 14 |
| Water, Quality and Treatment Manual-A.W.W.A | 14 |
| Water Supplies, Public-Turneaure and Russel | 14 |
| Water Works Handbook-Flinn, Weston and Bogert...- | 14 |

## APPENDIX I

## REFERENCES

## 1. Field Manuals (FM)

FM 5-5 Engineer Troop Units
FM 5-15 Field Fortifications
FM 5-20 Camouflage
FM 5-22 Camouflage Materials
FM 5-25 Explosives and Demolitions
FM 5-31 Use and Installation of Boobytraps
FM 5-34 Engineer Field Data
FM 5-36 Route Reconnaissance and Classification
FM 20-32 Land Mine Warfare
FM 21-10 Military Sanitation
FM 27-10 The Law of Land Warfare
FM 101-10 Staff Officers' Field Manual: Organization, Technical, and Logistical Data.
(S) FM 101-31 Staff Officers' Field Manual: Nuclear Weapons Employment (U).

## 2. Technical Manuals (TM)

TM 5-220
TM 5-232 Elements of Surveying
TM 5-233 Construction Surveying
TM 5-234 'Topographic Surveying
TM 5-235 Special Surveys
TM 5-250 Roads and Airfields
TM 5-251 Army Airfields and Heliports
TM 5-252 Use of Road and Airfield Construction Equipment
TM 5-260 Principles of Bridging
TM 5-270 Cableways and Tramways
TM 5-271 Light Stream-Crossing Equipment
TM 5-272 Widened Steel Treadway Bridge
TM 5-277 Panel Bridge, Bailey Type, M2
TM 5-285 Semipermanent Highway Steel Bridges, 30-, 60-, and 90-Foot Spans.
TM 5-286 Semipermanent Highway and Railway Trestle Bridges.
TM 5-295 Military Water Supply
TM 5-297 Wells

TM 5-301 Engineer Functional Components System Staff Tables of Installations, Facilities, and Equipages.
TM 5-302 Construction in the Theater of Operations
(O) TM 5-310

Military Protective Construction
TM 5-351 Gas Generating
TM 5-370 . Railroad Construction
TM 5-371 I-Beam Railway Bridge
TM 5-372 Unit Construction Railway Bridge
TM 5-373 Through Truss Railway Bridges
TM 5-541 Control of Soils in Military Construction
TM 5-634 Refuse Collection and Disposals; Repairs and Utilities.
TM 5-665 Operation of Sewerage and Sewage Treatment Facilities at Fixed Army Installations.
TM 5-666 Inspections and Preventive Maintenance Services, Sewage Treatment Plants and Sewer Systems at Fixed.Installations.
TM 5-680 Electrical Facilities, General, Engineering, Data and Practices, Tools and Equipment, and Safety Practices, Repairs and Utilities.
TM 5-681 Preventive Maintenance for Electrical Facilities
TM 5-704 Construction Print Reading in the Field
TM 5-760 Electrical Wiring
TM 5-765 Electric Power Transmission and Distribution
TM 5-766 Electric Power Generation in the Field
TM 9-1910 Military Explosives
TM 9-1946 Demolition Materials
TM 19-500 Enemy Prisoners of War
(C) TM 23-200 Capabilities of Atomic Weapons (U)

TM 38-230 Preservation, Packaging, and Packing of Military Supplies and Equipment.

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By order of the Secretaries of the Army and the Air Force:

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$N G:$ State AG (3); units-same as Active Army except allowance is one copy to each unit.
USAR: Units-same as Active Army except allowance is one copy to each unit.
For explanation of abbreviations used, see AR 320-50.



[^0]:    ${ }^{2}$ Information obtained from Corps of Engineers Technical Committee papers.

[^1]:    ${ }^{2}$ Information obtained from Corps of Engincers Technical Committee papers.

[^2]:    15 boxes, 3 chests, and 3 unboxed lterns will be carrled as part of loads in trucks, rollers, etc.

[^3]:    $1241 / 2$-lnch overhang. Point at whioh rear wheels of small vehicle rest on floor is only 3 or 4 inehes from end of truck platform.
    $241 / 2$-inch and 2514 -inch overliang. Point at which rear wheels of small vehlele rest on floor is only 1 to 2 inches from end of truck platform.
    3 -foot $1 \frac{1}{2}$-inch overhang. Trailer drawbar must be racked.
    4 Trailer is wider than truck body at point 2 or 3 inches higher than top of truck body side panel. Bow standards must be removed.
    s Same as note 4 except 4 to 5 inches higher. Also 3 feet $11 / 2$ inches to 3 feet.
    ${ }^{6} 2$-foot $41 / 2$-inch overhang. Traller drawbar must be racked.
    ${ }^{7}$ Same as note 4 except 4 to 5 inches higher. Also 2 -foot $41 / 2$-inch to 2 -foot 6 -inel overhang which requires that trailer drawbar he racked.

[^4]:    ${ }^{1}$ For rehabilitation of a site where an airfleld exists or has existed use 75 percent of the ahove factors.
    ${ }^{2}$ Battalion-months are computed on the hasis of 110,000 effective man-hours per month for one engineer construction battalion TOE $5-115 \mathrm{D}$, full strengtl.
    ${ }^{3}$ This figure will fluctuate due to site sclection and construction materlal seleetlon.

[^5]:    1 Witb $6,500-\mathrm{ft}$. by $150-\mathrm{ft}$. runway.

[^6]:    1 Breaks down into 6 subbundles of 5 each. 1 subbundle contains 2 half panels and 4 full panels. Eacb bundle of M-6 contains end connectors. Each bundle of PSP contains clips.

    2 Estimated-based on limited information.

[^7]:    See footnotes at end of table.

[^8]:    ${ }^{1}$ Being converted fronn ${ }^{3}$, s inch
    2 Kenya aud Ueanda.
    ${ }^{3}$ Not available
    1 Plus 28 miles of dual gage.

[^9]:    ${ }^{1}$ Excessive amounts cause suffocation.

[^10]:    ${ }_{2}^{1} A^{\prime}$ or $A^{\prime \prime}$ for medical gas minxtures.

[^11]:    ${ }^{1}$ Under certain conditions, 100 Ib . See Spec. PPP-B-621.

[^12]:    ${ }^{1}$ The object indicated (but not the foregoing one) can be pushed into the snow without considerable effort.

[^13]:    1 When practicable and if authorized by the commander of a divisigu or larger unit.

[^14]:    ${ }^{1}$ Material has no specification, is made up in camouflage colors commercially.

[^15]:    See footnotes at end of table.

[^16]:    ${ }^{1}$ Width of roadhed on fills should be for 2 feet grcater than in cuts.

[^17]:    1 Dead slow.

[^18]:    ${ }^{1}$ From arrival through fabrication.
    ${ }^{2}$ From arrival through fabrication, excluding span and tower erection.

[^19]:    Note 1. W=whecled vehicles; $\mathrm{T}=$ tracked vehicles
    2. Dual classification for elasses of 30 and above.
    3. Section modulus $\ln \ln ^{3}$.

[^20]:    Sec footnotes at end of table．

[^21]:    1 Not normally used.
    ${ }^{2}$ See ferric coagulants.

[^22]:    1 Calculated at 40 psi .

[^23]:    See footnotes at end of table.

[^24]:    See notes, following table 104.
    i The eurrent-earrying eapaelties for type RHI conduetors for sizes AWG14,12, and 10 shall be the same as designated for type RII conductors in this table.

[^25]:    See footnotes at end of table.

[^26]:    Sec notes, following table 104.
    *For threc wire, single phase service and sub-service circuits, the allowable current-carrylng capaeity of RH, RII-RW, RHI and RHW aluminum conductors shall be for sizes \#2-100 amp., \#1-110 amp., \#1/0-125 amp., \#2/0-150 amp., \#3/0-170 amp., and \#4/0-200 amp.
    ${ }^{1}$ The current-carrying capaclties for type RHII conductors for sizes AWG 12, 10, and 8 shall be the same as designated for type RH eonductors in this table.

[^27]:    ${ }^{1}$ Conductor loading per foot as specified in Jule 251, N ESC, 5 th edition.

[^28]:    1 Conductor loading ber foot is spucified in Rule 25I, NESC, fiffil edition.

[^29]:    ${ }^{1}$ Conductor loading per foot as specified in Rule 251, NESC, fifth edition.

[^30]:    ${ }^{1}$ Conductor loading per foot as specified in Rule 251, NESC, 5th edition.

[^31]:    ${ }^{1}$ Equal rations of each item.

[^32]:    1 Forms white fog when burned in presenee of ammonia.
    ${ }^{2}$ Halide lamp usually used. This consists of a flame-heated copper wire whieh in eontact with freon burns with a blut-green color.

[^33]:    ${ }^{1}$ Uniform rate of increase or decrease.

[^34]:    (Reprinted from "Steel Construction" by permission of American Institute of Steel Construction. Copyright 1947.)

[^35]:    ${ }^{1}$ Car and Stipbuilding Channel, not an American Standard.

[^36]:    ${ }^{1}$ Data extracted from Journal of the American Concrete Institute, May 1956. Reprinted by permission of A.C.I.

[^37]:    ${ }^{1}$ Quoted from pars. 506 and $\mathbf{1 3 0 3}$ of "Building Code Requirements for Reinforeed Concrete" adopted as a standard by the American Conerete Institute in 1956.

[^38]:    ${ }^{1}$ Material in this paragraph is taken, with minor changes in wording, from pp. 22 and 23 ; formula 30 on p. 96; table 9 on p. 52; dagram 17 on p. 58; and table 15 on p. 57, of the AC1 Reinforeed Conerete Design llandbook, second edition, 1955.

[^39]:    (Reprinted from Manual of Structural Design by Singleton by perimission of H. M. Ives \& Sons. Copyright 1947.)

[^40]:    See footnotes at end of table.

[^41]:    ${ }^{1}$ Based on sheets 27 inches wide, lapped 3 inches.
    (Reprinted from "Stccl Construction" by permisslon of American Institute of Steel Construction. Copyright 1947.)

[^42]:    Note. When high-frequency vibrators are used, the tabulated values should be reduced by 33 .

[^43]:    ${ }^{1} \mathrm{HP}$ indicates gradation for high-pressure tire traffic and potential jet aircraft pavements.

[^44]:    ${ }^{1}$ Stonc or gravel. ${ }^{2}$ Slag. $\quad{ }^{\mathbf{3}} 100$ percent passing $21 / 2$-inch sieve.

[^45]:    ${ }^{1}$ Weight per sheet, uncrated.

[^46]:    ${ }^{1}$ American National Form screw threads.

[^47]:    ${ }^{1}$ Ratio of loose thickness to compacted thickness assumed to be 1.25 to 1.

[^48]:    ${ }^{1}$ Compaction ratio assumed to be 1.25 to 1 .

[^49]:    1 long hundredweight (cwt.) $=1 / 20$ long ton $=4$ quarters $=8$ stone $=112 \mathrm{lbs} .=50.8024 \mathrm{~kg}$.

[^50]:    a Measured at a point one-third the length of the pile from the butt.
    ${ }^{b}$ Obtainable only with the heaviest miltary driving equipment.

