ENGINEERING ON THE FARM

STEWART

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A TREATISE ON THE APPLICATION OF ENGINEERING PRINCIPLES TO AGRICULTURE

By

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of Illinois, 1895-1922

RAND McNALLY & COMPANY
CHICAGO NEW YORK

18760

Made in U.S.A.

THE CONTENTS

CHAPTER PAGE

PART V. MECHANICAL EQUIPMENT

THE PREFACE

The development of agricultural lands necessitates a general knowledge of elementary engineering principles. The purpose of this volume is to explain and illustrate the practical application of these principles. The subjects treated and their method of presentation have been determined by nine years' experience in the class instruction of college, school, and short-course students and by correspondence and personal interviews with men familiar with the needs and desires of the ordinary landowners throughout the country. An effort has been made to eliminate everything of a technical nature and to explain in simple, clear language the engineering problems that most frequently confront the average landowner and agricultural student. The authors believe that the more important subjects are covered in sufficient detail to give the reader the practical information needed on a farm. Undoubtedly work has been omitted which would be of value in certain localities, but it is impracticable, in a book of this nature, to cover all points which might be of interest to special individuals.

A chapter on surveying has been omitted for well-defined reasons. The expense of instruments and materials for the proper performance of surveying work is such as to eliminate them from farm equipment. The agriculturist is sufficiently occupied with the problems presented by roads, drainage, irrigation, buildings, and similar matters, without attempting to master the details of manipulating a surveying instrument in the field or making the technical computations. For both satisfactory results and economy a trained engineer should be employed to lay out and map proposed improvements. The engineering skill of the agriculturist can then with profit be limited to the agricultural side of the problem. He should be sufficiently versed in the knowledge of engineering to be able to collect his part of the information and furnish it to the engineer and then coöperate efficiently in the work. Engineers employed in agricultural work usually spend a large portion of their time in collecting data that should have been collected and supplied by the landowner. A study of soils, classification of lands, and specific problems on any individual tract of land made by the agriculturist will greatly lessen the expense of improvements that involve engineering assistance. In the services of an engineer it is his experience and judgment that are needed and not merely the operation of the instrument in the field. The most expert instrument man might be a very undesirable engineering advisor. The trained eye and judgment of the professional engineer cannot with economy be acquired by the landowner or agricultural student, and for this reason no attempt has been made to incorporate in this volume instructional matter on surveying.

In the preparation of *Engineering on the Farm* the files of the Division of Agricultural Engineering, Department of Agriculture, University of Minnesota, have been freely drawn upon for illustrations and other data. Use has also been made of unprinted manuscripts and bulletins published by the authors and their co-workers in this division, particularly "Rope and Its Use on the Farm," by J. B. Frear, and "Cement and Its Use on the Farm," by E. C. Crane. All of these data were especially prepared in the division to accomplish the same purpose that is sought by this text. The authors wish to acknowledge their indebtedness to Miss Hazelle E. Baird for suggestions on the organization and English of the manuscript and for proofreading, and to the following members of the Division of Agricultural Engineering: L. R. Whitson, instructor in drawing; E. C. Crane, assistant engineer; and George F. Krogh, draftsman. The courtesy of the Du Pont de Nemours Powder Company, the Western Electric Company, the International Harvester Company of America, Deere & Webber Company, J. I. Case Threshing Machine Company, Inc., and the Link Belt Company is acknowledged for the use of cuts.

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Engineering on the Farm

PART I. INTRODUCTORY

CHAPTER I

RECORDS AND REPORTS

Necessity for clearness. All specialized work requires the use of notebooks for recording original data and other information, and the subsequent compilation of well-arranged and tabulated reports. These are frequently given too little attention by the employee recently out of school, and probably more new men are criticized for failure along this line than in any other.

There is a tendency to keep notes on scraps of paper loosely carried in the pocket, or in an unarranged notebook with other matters. Items are hurriedly written or incompletely explained, and after a few weeks the collector of the notes himself is not able to interpret his book with any degree of certainty, and another person can make nothing of it. Reports supposed to give a clear idea of a situation are written up without attention to the logical order of the events covered, details are omitted, and the reader is left in the dark as to the ideas which the writer intended to convey.

The man engaged in the collection of information required for future use should keep such a record that doubt cannot exist in his own mind as to the interpretation, and a second person can take the notebook and interpret the data correctly and rapidly after a short study. Reports should be clear and concise, carrying to the reader the exact information that has been developed by the field record. In other words, the assistant, by means of his notebook and report, presents to his superior such facts as will enable the superior to understand conditions as they exist on the ground and to have practically the same knowledge as if he had collected his own information. Materials and methods best adapted to secure intelligible records and reports are discussed below.

MATERIALS

Notebook. A notebook should be selected with pages of suitable size and properly ruled for the data. When consistent with other requirements, a size that will go into a side coat pocket is desirable. The book should at all times be carried in a pocket from which it cannot be lost. The hip pocket is objectionable because riding in a seat or saddle may cause it to be worked out. If carried in an inside or front coat pocket, it may slide out while the owner is crawling under a fence or lying down to drink. A buttoned flap over the pocket protects the notebook from loss, as it holds the book in place regardless of the posture of the owner. A notebook binding should be strong enough to stand the wear of the pocket, and the paper should be so tough that it will not be torn by the wind. Lines should be ruled with an ink that will reduce blurring to a minimum when wet. For office use, books properly ruled and of suitable size are satisfactory, as requirements of field service do not necessarily apply.

Pencils. Field records are best made with a lead pencil. The pencil used for recording should have a sharp point of hard lead, 4H to 6H, a 5H being preferable. A fountain pen should not be used, as the ink freezes in cold weather, dries on the pen when exposed to wind, or becomes exhausted when the pen cannot be refilled. Sufficient pressure should be applied to a pencil to score the paper and thus prevent obliteration of the notes. If the notes have been properly kept, when the page is held up to the light the figure or word can be read even though the lead has been removed by rubbing or by water. Soft pencils that do not score the paper are objectionable for original records, since rubbing of the page or a drop of water may spread the lead and cause the entire page to become illegible. For office use soft pencils are preferable, because erasing is desirable.

Erasers. Erasers should not be used in field work, for it is bad practice to efface an original record or figure. Errors are frequently made in the attempt to correct what has once been recorded, and if the original can be read, it may assist in the locating of the error. Erasers are necessary in sketch work and in office computations. Soft erasers with a small end are best, for they minimize the possibility of rubbing out parts that are correct. Since the stroke of an eraser destroys the reflecting surface, its use can always be detected on a notebook or drawing if the paper is held in front of the eyes in such a position that the page reflects the light.

METHODS

Title. Before field entries are made in a book, a title should be placed on the flyleaf or first page. Many offices employing field recorders send out their notebooks with a title page printed in blank, containing a full description of what should be done with the book by the finder in case it is lost. This title should contain the name of the firm or organization for whom the work is being done, the class of work covered, the location of the work, the name of the immediate superior, the name of the recorder, the date on which the first records are made, and, upon completion of the book, the date of the last record.

Checking. Original records should be recorded directly from the work or instrument used, and a systematic method of checking should be employed. If there is a second person available, he should, if competent, check the recorded data. In direct readings or computations the comparative check should not be made until after the results have been recorded. There is a psychological condition of the mind which causes it to repeat what has previously been heard, and consequently there is a tendency, if the recorder makes a reading. for the checker to make exactly the same reading, even though it is an error, owing to the fact that he knew the results obtained by the recorder.

All original records and computations should be made on the assumption that errors will occur, and every possible method of eliminating them should be used. It frequently happens that one person makes a wrong record and another a wrong computation and the results check. One mistake balances the other. Where practicable, it is well for some third check method to be used. A new employee should not resent frequent checking of his work by other assistants or superiors who may have had more experience and understand the necessity of carefully guarding against errors. The experienced man is always willing to have his data checked in every way possible.

The copying of notes introduces a source of error, and the original records should be preserved and sent in even though they may not be as presentable as a copied record. Notes which are copied should be marked "Copy" and reference made to the location of the originals.

Correcting errors. When an error is found in a recorded figure, a light line should be drawn through the figure and the correct one placed above it. This clearly indicates to the reader that the figure has been canceled and corrected, and the original is still legible. A correction made by erasing, writing one figure on top of another, or changing a figure is generally indistinct and confusing.

Clearness of terms. Words and terms used should be explicit and those with two meanings avoided. Technical terms should not be employed unless they have become standardized and are known to be familiar to all those who would probably have occasion to make use of the data. The terms "right" or "left" hand have no definite meaning, and have no place in a notebook unless the recorder has clearly explained in what direction he was facing when he used the words "right" and "left." The terms "right" and "left" are definite only when associated with a stream or river.

Where the words "pace" or "step" are used, the record should show in the beginning the exact length of stride.

Arrangement of data. In arranging data make it a rule to keep all records in logical order. Where this is not practicable, reference should be made to other parts of the book from which or to which the data are continued. When conditions make it impossible to complete a certain line of work, it is best to begin new work on the following page rather than estimate and leave blank the number of pages that will be needed for completion. When the former work is again taken up, the first line on the page should indicate the page and book from which it is continued ("Continued from Book 1, page 45"), and the last page on which the work is found should indicate the page and book to which it has been continued ("Continued in Book 6, page 48").

Notes should not be crowded in such a way that they will be confusing or illegible. Neither should they be written so open and large that they take up an unnecessary amount of space. Judgment must be used by the recorder in discriminating properly between crowded and loose work. Wherever the subject changes, a heading large enough to attract the eye should be inserted. When a subject is completed, the word "End" should be written. If there are many different subjects in the book, an index should be made on either the first or the last pages. The last pages are more desirable, but wherever the index is placed in the first book of a series the same practice should be followed in the others.

Appearance. In the preparation of reports and plans, attention should be given to their general appearance, as the first impression of the ability of the author is gained from the general appearance of his work. The scale of drawings should be such that all of the data may be clearly shown without crowding. It should not be of sufficient size to require cumbersome sheets when the same information might be as readily given on smaller ones. The drawings should be trimmed even and true, and when borders are used they should be placed at a uniform distance from the edge. The surface of the paper and the gloss of the ink lines should not be destroyed by too much erasing or by the use of hard erasers. Ink erasers, of either steel or rubber, must be used with care or holes will be worn in the paper. In the making of a drawing, from the start thought should be given to its final appearance and care should be taken to reduce to a minimum the erasing necessary to clean it. To be presentable the final drawing should be free from dirt, pencil, and score marks. After the work has been completed, it should not be injured by being folded or rolled in such a way that it will be crushed together and permanent creases made in the individual sheets. The appearance of many a neat drawing has been seriously impaired by crushing of the roll.

Author's signature. Original work, either drawings or reports, should be signed in the hand of the author. This carries with it a certain individuality and indicates that the author has given the matter his personal attention. A name which is put on by the draftsman or assistant should be printed rather than written.

The method of signing the name is important. There is a tendency for an inexperienced person to sign his name in two or more ways. In governmental transactions and in legal procedure only one signature is recognized. For example, the United States government and the courts will not assume that John T. Stewart and J. T. Stewart are the same person. The signing of a man's name in two different ways has often led to serious delay and costly errors. As this matter of signature is one of habit, each person, early in life, should select a distinguishing signature and always write his name the same.

The foregoing suggestions concern only little things which may seem unimportant, but when neglected they may be the cause of embarrassment or serious inconvenience. Proper attention to them will be one of the first stepping stones to advancement.

CHAPTER II

MEASUREMENTS

There are in use today for the measurement of length, area, and volume two distinct systems, known as the English and the metric. While the English weights and measures are used almost exclusively on the farm, there are times when some knowledge of the metric system is very convenient.

ENGLISH MEASURE

Yard and foot. The basis of the English system is the *imperial yard*, the standard length of which is the distance between two points on a metal rod kept in the Tower of London at a temperature of 60° Fahrenheit. The tendency at the present time is to discontinue the use of the yard as a unit of measurement. The only general use it still retains is in athletics, for measuring dry goods, and for expressing the range of firearms. The common unit of measurement, and the one to which practically all others are reduced for comparison, is the *foot*, the equivalent of one-third of a yard. The foot is divided into two different units, the inch and the tenth. The *inch*, used in mechanical measurement, is one-twelfth of a foot, its subdivisions being indicated by common fractions, such as half-inch, fifteen-sixteenths inch, etc. The *tenth* is one-tenth of a foot, and its subdivisions are always decimal parts of the larger unit.

Since computations involving common fractions become very cumbersome, the tenth or decimal subdivisions are more convenient for computations than the inch and fractional subdivisions.

The tables on the following page will be helpful when such computations are to be made.

TABLE SHOWING THE EQUIVALENT OF THE FRACTION OF AN INCH IN DECIMALS OF A FOOT

Inch	Foot	Inch	Foot	Inch	Foot	Inch	Foot
0	0	1/4	.0208	1/2	.0417	3/4	.0625
1/32	.0026	9/32	.0234	17/32	.0443	25/32	.0651
1/16	.0052	5/16	.0260	9/16	.0469	13/16	.0677
3/32	.0078	11/32	.0286	19/32	.0495	27/32	.0703
1/8	.0104	3/8	.0313	5/8	.0521	7/8	.0729
5/32	.0130	13/32	.0339	21/32	.0547	29/32	.0755
3/16	.0156	7/16	.0365	11/16	.0573	15/16	.0781
7/32	.0182	15/32	.0391	23/32	.0599	31/32	.0807

TABLE FOR REDUCING DECIMALS OF A FOOT TO INCHES AND THE NEAREST 1/8 INCH

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.....	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8
.1	1 1/4	1 3/8	1 1/2	1 5/8	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4
.2	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/8	3 1/4	3 3/8	3 1/2
.3	3 5/8	3 3/4	3 7/8	4	4 1/8	4 1/4	4 3/8	4 1/2	4 5/8	4 5/8
.4	4 3/4	4 7/8	5	5 1/8	5 1/4	5 3/8	5 1/2	5 5/8	5 3/4	5 7/8
.5	6	6 1/8	6 1/4	6 3/8	6 1/2	6 5/8	6 3/4	6 7/8	7	7 1/8
.6	7 1/4	7 3/8	7 1/2	7 5/8	7 5/8	7 3/4	7 7/8	8	8 1/8	8 1/4
.7	8 3/8	8 1/2	8 5/8	8 3/4	8 7/8	9	9 1/8	9 1/4	9 3/8	9 1/2
.8	9 5/8	9 3/4	9 7/8	10	10 1/8	10 1/4	10 3/8	10 1/2	10 5/8	10 5/8
.9	10 3/4	10 7/8	11	11 1/8	11 1/4	11 3/8	11 1/2	11 5/8	11 3/4	11 7/8

Example: To reduce .35 of a foot to inches, follow the .3 line to column headed .05, which gives the equivalent in inches—4 1/4.

AMERICAN USAGE

Surveyors' chain. Unfortunately in this country it has become the custom to use certain units for specific purposes. While they are all reducible to a common unit, the foot, persons employed in certain occupations recognize only the special units, and unless measurements are given in such units do not readily interpret them. In land measurements the United States Land Office recognizes the use of the chain as the standard, with the link as the subdivision. The *chain* is referred to in several ways, as Gunter's chain, surveyors' chain, four-rod chain, four-pole chain, and four-perch chain. A *link* is one-hundredth part of the chain. The equivalent of the chain is 66 feet; of the link, 7.92 inches.

Rod. The common term for expressing land lineal units on the farm is the *rod*, which is one-fourth of a chain, or 16½ feet. The terms *perch* and *pole* are used to refer to the same unit. The terms "pole" and "rod" probably originated from the use of a slender piece of wood cut to the required length and used for the measurement of land.

Mile. The common term for expressing distances of travel is the *mile*, which is equivalent to 80 chains or 320 rods or 5,280 feet, a quarter-mile being 20 chains, 80 rods, or 1,320 feet.

Engineers' chain. Civil engineers in all classes of work except land surveys use the *engineers' chain*, a chain 100 feet long subdivided into feet and decimals of a foot. It is customary, even in measuring land, to use the 100-foot chain and then reduce the measurements and record them in terms of the surveyors' chain, thus avoiding two units of measurement. Care should be exercised, in the discussion of land measurements, not to confuse the 66-foot chain with the 100-foot chain used in other engineering. In land surveys the chain is always 66 feet.

Station. The term *station* is used to indicate one length of a unit of measurement as marked on the ground by stakes. It is not necessarily a fixed unit. Unless otherwise qualified, it may be considered as 100 feet in length. The station number is indicated on the stake which marks the far end of the station from the starting point. When the stake is at the end of the chain, a figure is placed on the stake indicating the number of stations. For example, if the chain has been stretched out eight times, the stake at the far end of the last chain will be marked "8," indicating that the stake is out eight stations on the line. The station number multiplied by the number of feet in the unit of measurement gives the distance in feet of the outer stake from the starting point. Consequently where a 100-foot chain is used station "8" is 800 feet from the starting point.

There are sometimes reasons for placing stakes at other points than at the end of the chain. For example, it may be desirable to place a stake 21 feet beyond the station "8." This fraction of a station is usually referred to as a *plus*. In railroad work the stake marking the point 21 feet beyond station "8" would be "8+21." Some engineers prefer to mark the stake indicating the same point as "8$^{\underline{21}}$," while others mark it "8.21." These three markings all mean the same thing: that the distance from the starting point to the stake so marked is 8 stations and 21 feet on the next station, or 821 feet. The expressions "Take a plus" or "What is the plus on that point?" are understood to refer to the number of feet beyond the last regular station.

Spanish unit. In the extreme southern part of the United States, from Florida to California, there are lands which passed into private ownership while that territory was a part of the Spanish possessions. As a result, all lands surveyed previous to American possession are recorded in the Spanish unit, the *vara*. Since the territory became a part of the United States, the equivalent of the *vara* in inches has been sanctioned by the United States Land Office as 33 inches in California. In Texas it is 33⅓ inches, in Mexico 32.9931 inches.

French unit. Areas of the United States in the vicinity of New Orleans and other points settled under French control have distances recorded in the *pied du roi*, which is equivalent to 12.789 inches.

METHODS OF DETERMINING DISTANCES

Estimating. Estimating is the approximate determination of distance between two points and is made by visual inspection. Frequently it is possible to see some known object by which comparison can be made. Experience in using an object of known dimensions for estimating distance may be acquired and give fairly accurate results.

Distances may be estimated by the time of walking, riding, driving, or rowing between points within fairly close limits. The success of these methods depends upon the uniformity of the rate at which the traveling is done and upon frequent checking of the rate of movement over a known distance. Skilled oarsmen can acquire great accuracy in rowing a boat a given distance in a given time.

Pacing. Pacing is the method of determining distance by keeping count of the number of steps taken. Considerable skill may be developed in pacing if one gives some attention to it and frequently checks the pace over a known distance. The term *pace* indicates the distance covered by the individual stride of a person. In military organizations the pace is fixed at 30 inches, but in civil life it has no definite length and is whatever distance the person using it naturally covers at one stride. Consequently, where the pace is used, the equivalent in feet should be definitely stated. When one is going uphill, the pace will be shortened somewhat, and downhill it will be lengthened. Either one or both feet may be counted as they strike the ground. A natural stride should be taken, as more correct results are obtained when no mental effort is being spent on the length of stride. In riding or driving the pacing method can be used by means of counting the steps of either the fore or hind feet of the horse. As a rule, the horse steps more uniformly than a man. The pace should always be stated in feet. The number of paces in a given number of feet may be determined by measurement of a given distance after it has been paced.

One of the errors in pacing is caused by losing count of the strides taken. The number of paces carried in the mind usually should not exceed 100. When the count reaches 100, record should be made in a notebook or by means of placing some small object in an empty pocket. The fingers may be used if a finger on the right hand is closed each time one hundred paces are covered. When all the fingers on the right hand are closed, it indicates that five hundred paces have been counted. One finger on the left hand can then be closed and all on the right hand opened up. In this manner the left hand is tallying five hundred paces, the right hand one hundred paces, and the mind the individual pace. The only objection to this method is the danger of straightening the fingers when one is spoken to or stumbles on rough ground.

Wheel revolutions. Wheel revolutions on level ground give more correct results than pacing. An ordinary buggy or wagon wheel can be used if one of the spokes is marked with a piece of cloth near the rim. The number of revolutions of the wheel between the given points multiplied by the distance around the tire of the wheel gives the required measurement. The tendency of the wheel to slide going up and down hill decreases the accuracy of this method. Bicycles and automobiles are usually provided with measuring devices of this type. There is a mechanical arrangement that measures the number of revolutions, and the exact distance passed over can be read from a dial. A similar device can be purchased for use on a buggy or other wheel vehicle. If such a device is used, care should be taken to adjust the instrument to the circumference of the wheel. A device that would give accurate results on a wheel 9 feet in circumference would not give accurate results on a 10-foot wheel. If a recording device is to be changed frequently from one vehicle to another, it is better to purchase one that records revolutions and not direct distances, as the distance may be computed by multiplication of the number of revolutions by the circumference of the wheel.

Chaining. The common method of determining distances between points in measuring lands, roads, and fields is by passing between the points with a measuring line of standard length. These lines are known as metallic tapes, steel tapes, chains, etc. (Fig. 1). They vary in length from a few feet up to 300 feet.

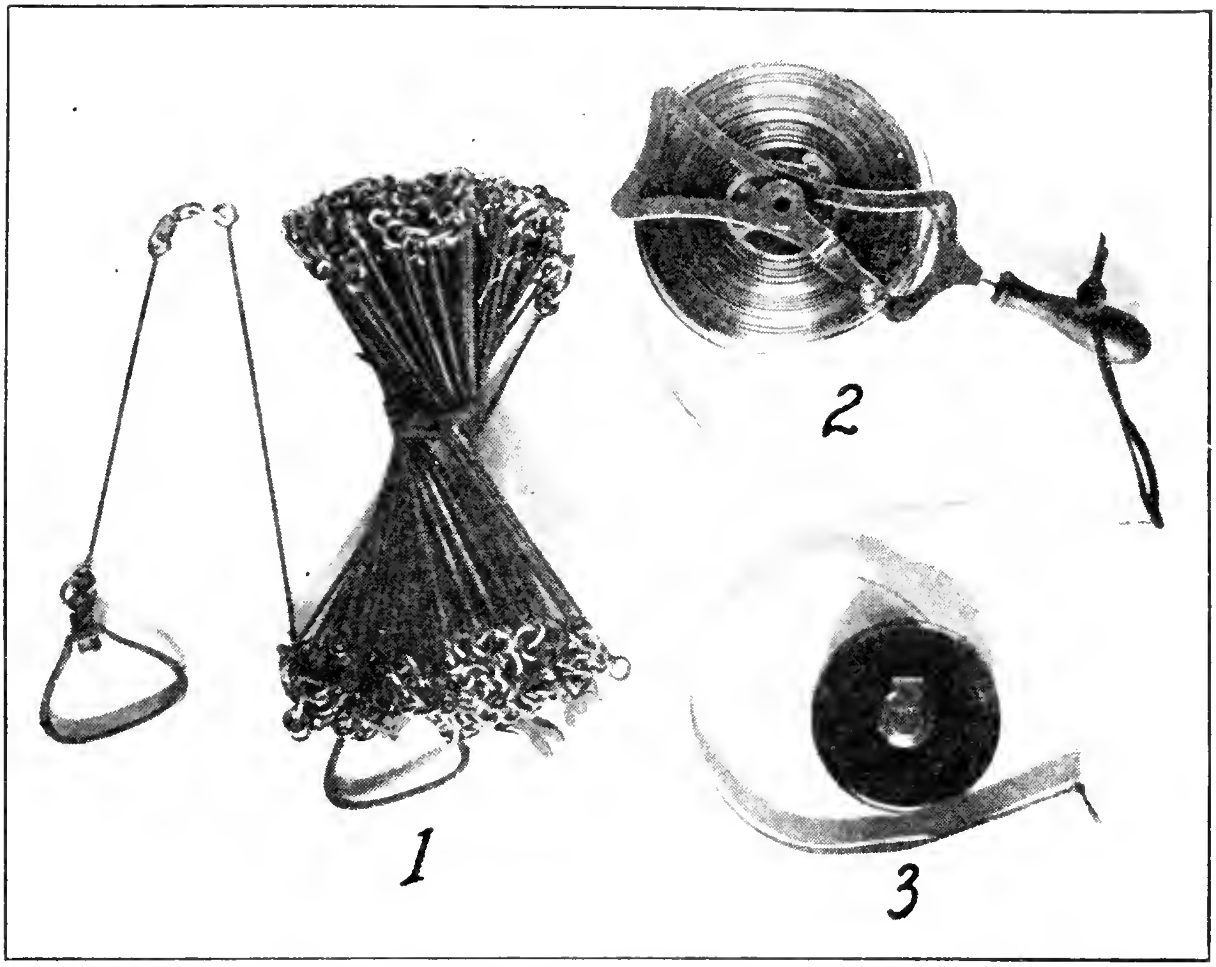

FIG. 1. *(1) Surveyors' chain; (2) engineers' steel tape; (3) metallic tape*

Metallic tape. A metallic tape is usually 50 feet in length and can be wound up in a small sole-leather case. It derives its name from the fact that there is a number of metal threads running lengthwise through the body of the tape, which is a woven fabric. The object of the metal threads is to prevent stretching. Similar tapes without metal threads are known as linen tapes. They are much cheaper and will stretch with use.

Steel tape. Steel tape is a narrow ribbon of steel similar to a watch spring. For engineering measurements it is

100 feet in length. For land-survey work it is 66 feet long. A steel tape is an accurate instrument for measurement, but is rather delicate and requires careful handling. It rusts when exposed to moisture and is easily broken when driven over, tramped upon, or pulled when it has crossed itself. The principal error in the use of the steel tape is due to changes in temperature. Tapes are accurate with a 12-pound pull when the temperature is 62° Fahrenheit. A 10-degree change in temperature above or below 62° will lengthen or shorten a 100-foot tape 0.0756 inch. This is not appreciable in a single tape length, but when a measurement is carried through for a mile the accumulated error is 4 inches. It can readily be seen that if a line is measured when the temperature is 90° and then remeasured when the temperature is 10° below zero, there will be considerable difference in the two lengths owing to expansion and contraction, although the measurements are made by the same man with the same tape. It is difficult to stretch a tape in a high wind, and in measurements made through tall grass, weeds, or bushes considerable time is required to keep the tape straight, as it has a tendency to lodge in vegetation, and pulling from the ends does not straighten it.

Chains. The surveyors' and the engineers' chains are made of either iron or steel, the longer parts of the links being connected by three small rings known as *joints.* This number of loose parts in each joint necessary to make the chain flexible introduces eight wearing surfaces. When each of these surfaces is worn one-hundredth part of an inch, the resulting error in a 100-foot chain is 8 inches. Grass and mud collecting in the joints of a chain may cause a short measurement by preventing the wearing surfaces from coming into contact. This is frequently the cause of error when there is moisture on the vegetation or on fresh earth. Pulling the chain around a fence post or small tree may shorten the entire chain by bending the links. The pull in stretching the chain is not sufficient to straighten bent links. In passing through heavy vegetation there is a tendency for several of the links to double back over themselves in a knot, thus shortening the chain 2 or 3 feet. Consequently the chainmen should be continually on the alert to see that their chain is properly stretched and straight.

Length and zero point. Measuring equipment made by different manufacturing firms varies somewhat in the details of graduation and in the location of the *zero point.* Chains and tapes of special length are frequently used. In beginning a series of measurements with any kind of chain or tape the chainmen should first determine the length of the unit and the location of the zero point. An examination of the unit will determine the *length*, and the *zero point* on the end foot can be determined by comparison of that link or foot with a link or foot near the center of the chain or tape.

Errors in lineal measurement. Two sources of error must be guarded against in all lineal measurements. One is the small errors that continuously increase, such as expansion, worn links, and the like. The other is the error resulting from individual blunders by men making the measurements. The blunders can usually be traced to one of the following causes: loss of a tally pin, which means that the distance is shortened one unit length; loss of a tally, which means an error of 10 unit lengths; the wrong reading of a fractional tape, which means an error of 1 to 50 feet in a 100-foot chain or 1 to 33 feet in a 66-foot chain; failure to set the pins marking the chain lengths vertical, which means an error of 1 to 3 inches in each chain; not pulling the tape in straight lines, which gives an error increasing with the distance which the chain may be off the line; not holding the tape level on sloping ground, which means measuring the hypotenuse of a triangle when the base should be measured; not carrying the end of the tape straight to the

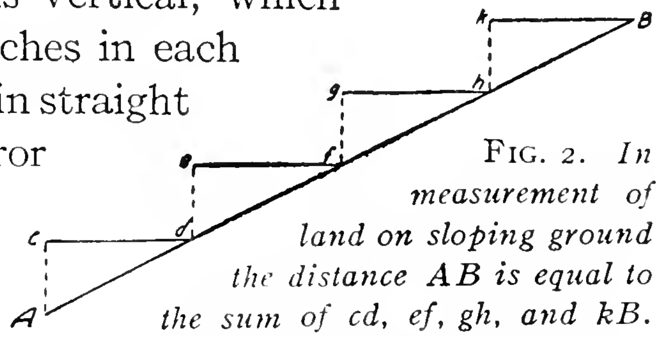

FIG. 2. *In measurement of land on sloping ground the distance AB is equal to the sum of cd, ef, gh, and kB.*

ground when the end is held high on sloping ground (Fig. 2). The uniform pull to be exerted by the chainmen on a chain or tape 100 feet long is approximately 12 pounds.

Area measurements. In measurements of area the same units are used as in lineal measurements, except that the measurement extends in two directions. The common term for expressing area measurements and their equivalents in feet are: by the *square foot*, equivalent to 144 square inches, used to express floor, window, wall, and other areas and limited to no definite line of work; and the *square yard*, equivalent to 9 square feet, a larger unit of area usually applied to plastered walls, paved areas, carpets, etc. The *acre* is the standard unit for land measurements and is equivalent to 10 square chains or 160 square rods or 43,560 square feet. When it is desired to express the extent of large areas of land, the term *section* or *square mile* is used, each of which is theoretically the equivalent of 640 acres. In very large areas of land the term *township* is used. Theoretically, this is a tract of land 6 miles square, containing 23,040 acres. Actually, the government section or township seldom contains the exact theoretical amount, owing to the conditions explained in the chapter on land surveys.

Surfaces. The circle contains a greater area than any other plane figure bounded by an equal perimeter or outline. The areas of circles are to one another as the squares of their diameters. Any circle the diameter of which is double that of another contains four times the area of the other. The area of a circle is equal to the area of a triangle the base of which equals the circumference and the perpendicular of which equals the radius.

Diameter × 3.14159 = circumference
Diameter × .8862 = side of an equal square
Diameter × .7071 = side of an inscribed square
Diameter squared × .7854 = area of a circle
Radius × 6.28318 = circumference
Circumference ÷ 3.14159 = diameter

The area of a parallelogram equals the base times the perpendicular height. The area of any triangle equals the base times one-half the perpendicular height. The surface of a right cylinder equals the area of both ends + the length times the circumference. The surface of a sphere equals the diameter squared times 3.14159, or the diameter times the circumference.

Volume measurements. Measurements of volume are generally made by means of the gallon or cubic foot. The United States *gallon* is equivalent to 231 cubic inches. The gallon is replaced by the cubic foot in large computations. The *cubic foot* is the equivalent of 1,728 cubic inches or 7.4805 gallons. In computations where accuracy is not required, 7½ gallons are considered the equivalent of a cubic foot.

LIQUID MEASURE

4 gills	1 pint
2 pints	1 quart
4 quarts	1 gallon

(Barrels are made in various sizes, but 31½ gallons is the standard.)

DRY MEASURE

2 pints	1 quart
8 quarts	1 peck
4 pecks	1 bushel

(The legal bushel in the United States, which contains 2150.42 cubic inches, varies from that of the English standard, which contains 2218.2 cubic inches.)

The table on page 18 gives the legal number of pounds per bushel of various agricultural products in the state of Minnesota. The practice is very nearly uniform throughout the country, and little variation from these weights will be found in any of the states.

Weight. The 16-ounce *pound* is the common unit of weight measurement. For larger quantities the *ton*, equivalent to 2,000 pounds, is used, and in a very few cases the *long ton*, equivalent to 2,240 pounds.

LEGAL WEIGHTS OF VARIOUS AGRICULTURAL PRODUCTS IN THE STATE OF MINNESOTA

	Lb. per Bu.		Lb. per Bu.
Alfalfa seed	60	Oats	32
Apples (green)	50	Onions	52
Apples (dried)	28	Onion sets (bottom)	32
Barley	48	Onion sets (top)	28
Beans (navy)	60	Orchard grass seed	14
Beans (lima)	56	Parsnips	42
Beans (broad Windsor)	47	Peaches (not dried)	48
Beans (scarlet runner pole)	50	Peaches (dried)	28
Beans (white runner pole)	50	Peanuts	22
Beets	50	Peas (smooth)	60
Blue grass seed	14	Peas (wrinkled)	56
Broom corn seed	57	Potatoes (Irish)	60
Buckwheat	50	Potatoes (sweet)	55
Carrots	45	Plastering (hair washed)	4
Chestnuts	50	Plastering (hair unwashed)	8
Clover seed	60	Rape seed	50
Corn (ear)	70	Redtop seed	14
Corn (shelled)	56	Rhubarb	50
Corn (sweet)	48	Rutabagas	52
Cranberries	36	Rye	56
Cucumbers	48	Sorghum seed	57
Flaxseed	56	Spelt or speltz	40
Hempseed	50	Timothy seed	45
Hickory nuts	50	Tomatoes	50
Hungarian grass seed	48	Turnips	55
Lime	89	Walnuts	50
Millet	48	Wheat	60

METRIC SYSTEM

Many foreign countries have discarded all of the local units of measurement and have accepted the meter as the standard unit of length, the *gram* for weight, the *liter* for liquids, and the *are* for land measurement. The *meter* is a unit in the decimal system and obviates all common fractions, any unit being either a subdivision or a multiple by 10 of the standard unit. The official meter is the distance between two marks on a metal rod kept in Paris, France

(Fig. 3). It is made of 90 per cent platinum and 10 per cent iridium. The length of the meter is equivalent to one ten-millionth part of a quadrant of the earth's meridian from the equator to the pole.

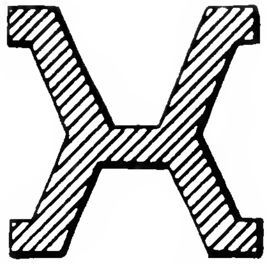

FIG. 3. *Cross section of the standard meter bar*

Subdivisions in the metric system are indicated by prefixes to each of the standards: "deci" for $\frac{1}{10}$, "centi" for $\frac{1}{100}$, and "milli" for $\frac{1}{1000}$. Multiples of the standard units are indicated by the prefix "deka" for 10 times, "hecto" for 100 times, and "kilo" for 1,000 times. There is a very close relationship between the various units, a *liter* being 1 cubic decimeter, the *are* 1 square dekameter, and the *gram* the weight of 1 cubic centimeter of water at maximum density.

The following tables of the metric system and the metric conversion table should furnish all the information on this subject needed by the average person:

LENGTH

10 millimeters	1 centimeter
10 centimeters	1 decimeter
10 decimeters	1 meter
10 meters	1 dekameter
10 dekameters	1 hectometer
10 hectometers	1 kilometer

MASS

10 milligrams	1 centigram
10 centigrams	1 decigram
10 decigrams	1 gram
10 grams	1 dekagram
10 dekagrams	1 hectogram
10 hectograms	1 kilogram

CAPACITY

10 milliliters	1 centiliter
10 centiliters	1 deciliter
10 deciliters	1 liter
10 liters	1 dekaliter
10 dekaliters	1 hectoliter
10 hectoliters	1 kiloliter

The square and cubic units are the squares and cubes of the linear units.

METRIC CONVERSION TABLE

Millimeters × .03937 = inches
Centimeters × .3937 = inches
Meters × 3.281 = feet
Kilometers × .621 = miles
Square centimeters × .155 = square inches
Square meters × 10.764 = square feet
Hektare × 2.471 = acres
Cubic centimeter ÷ 16.383 = cubic inches
Cubic meters × 35.315 = cubic feet
Liters × 61.022 = cubic inches (Act of Congress)
Liters × .2642 = gallons (231 cu. in.)
Liters ÷ 28.316 = cubic feet
Kilograms × 2.2046 = pounds
Kilowatts × 1.34 = horse-power

MISCELLANEOUS MEASURES

Circular measure. Circular measure gives the position of an object on the circumference of a circle. The unit of measurement is the *degree*, equivalent to $\frac{1}{360}$ of the circumference. Each degree is divided into 60 *minutes*, and each minute into 60 *seconds*. Circular measure, when expressed in degrees, indicates the amount of change in position of an object with reference to some fixed point on the circumference, but it does not give the distance actually traveled by the object in making the change unless other definite distances relating to the circle are expressed. For example, from a given point an object has moved 90°, or a quarter of the way, around the circumference, but the actual distance traveled by the object cannot be determined unless the radius or other distances are known (Fig. 4).

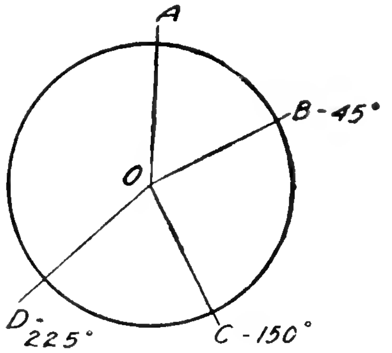

FIG. 4. *The location of an object on a circle can be described without reference to distance. If an object located at A moves to B, it has changed its position 45°. If it moves around to C, it has changed 150°, and if it moves to D, 225°.*

Special measures. The following special measures are in use:

Miners' inch. For the measurement of water flowing in streams and ditches in the western part of the United States, the term *miners' inch* was used in irrigation and hydraulic mining and the terms gallon and cubic foot were used in the central and eastern part. Owing to the fact that the use of the gallon and the cubic foot for expressing volume of water often necessitates the use of many figures, and the miners' inch does not mean the same in different states, two other units of liquid measure have been developed and are now universally accepted over the entire country.

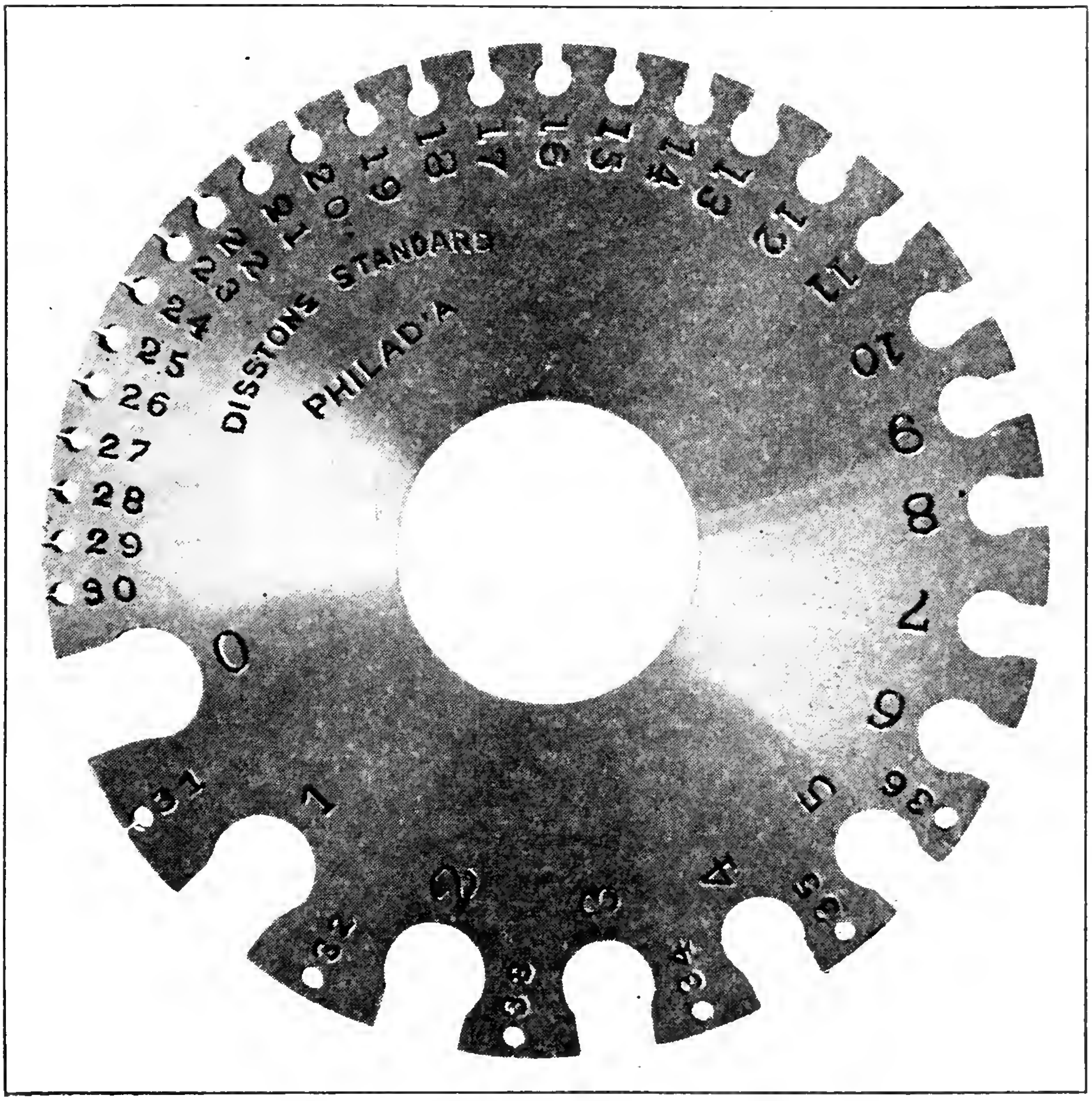

Fig. 5. *Standard wire gauge, full size*

Second-foot. The flow of a stream is indicated by the number of second-feet. A *second-foot* is 1 cubic foot of water passing a given point in 1 second of time. For example, a stream flowing 10 second-feet means that 10 cubic feet of water pass a given point each second.

Acre-foot. The *acre-foot* is a common term in irrigated country and is also used by soil men. It means a depth of 1 foot over an area of 1 acre and is equivalent to 43,560 cubic feet or 325,851 gallons. For example, if it requires 3 acre-feet of water to produce an acre of wheat, it is understood to mean that sufficient water must be applied to that acre of wheat so that if all the water were placed on it at one time the water would be 3 feet deep over the acre.

Wire gauge. The thickness of sheet metal and the diameter of wire and other small iron or steel material such as nails, screws, etc., are designated by a specific number which is measured by a wire gauge (Fig. 5, page 21). Unfortunately the wire gauges are not standardized, and in using the gauge it is necessary to specify the gauge name, as thickness indicated by one gauge varies from thickness indicated by the corresponding number of another gauge.

TABLE SHOWING A COMPARISON OF WIRE GAUGES IN DECIMALS OF AN INCH

No.	London	Birmingham Stubs	Brown & Sharp's American	No.	London	Birmingham Stubs	Brown & Sharp's American
0000	.454	.454	.460	19	.042	.042	.035
000	.425	.425	.409	20	.035	.035	.031
00	.380	.380	.364	21	.031	.032	.028
0	.340	.340	.324	22	.029	.028	.025
1	.300	.300	.289	23	.027	.025	.022
2	.284	.284	.257	24	.025	.022	.020
3	.259	.259	.229	25	.023	.020	.017
4	.238	.238	.204	26	.020	.018	.015
5	.220	.220	.181	27	.018	.016	.014
6	.203	.203	.162	28	.016	.014	.012
7	.180	.180	.144	29	.015	.013	.011
8	.165	.165	.128	30	.013	.012	.010

COMPARISON OF WIRE GAUGES—*Continued*

No.	London	Birmingham Stubs	Brown & Sharp's American	No.	London	Birmingham Stubs	Brown & Sharp's American
9	.148	.148	.114	31	.012	.010	.008
10	.134	.134	.101	32	.011	.009	.007
11	.120	.120	.090	33	.010	.008	.007
12	.109	.109	.080	34	.009	.007	.006
13	.095	.095	.071	35	.009	.005	.005
14	.083	.083	.064	36	.007	.004	.005
15	.072	.072	.057	37	.006	....	.004
16	.065	.065	.050	38	.005	....	.003
17	.058	.058	.045	39	.005	....	.003
18	.049	.049	.040	40	.004	....	.003

Time. The unit of time is determined by the average length of time between two successive passages of the sun across the observer's meridian, known as the *mean solar day*, consisting of 24 hours, each hour subdivided into 60 minutes and each minute into 60 seconds.

Temperature. The degree of heat or cold is measured by a thermometer. The Fahrenheit (F.) is used for ordinary work and the centigrade (C.) for scientific purposes. They compare as follows:

32° F. = 0° C.
212° F. = 100° C.
Fahrenheit temperature = $(\frac{9}{5}\text{ centigrade}) + 32°$
Centigrade temperature = $(\frac{5}{9}\text{ Fahrenheit}) - 32°$

Direction. Direction is expressed by the use of the terms north and east and their opposites south and west. North is a fixed point near the pole or North Star. A north line, or a *meridian*, is a line passing from the observer to the north point. Since persons in different parts of the earth's surface looking north are observing the same point, north lines are not parallel, but are converging and

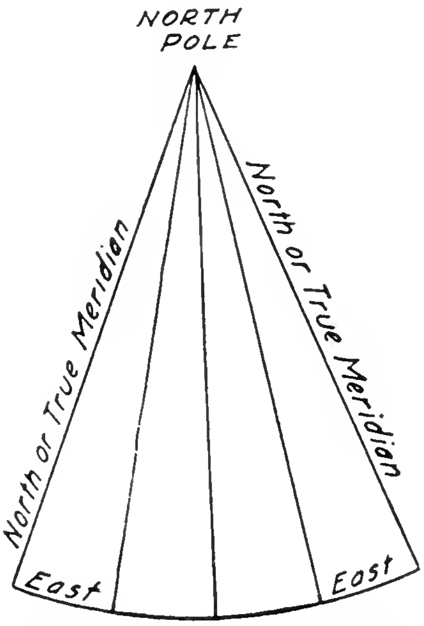

FIG. 6. *Showing the convergence of the meridians or north lines*

meet at the common north point (Fig. 6). An east line is a line which at all points is at right angles to the meridian at that point, or is a line all points of which are the same distance from the north point.

Methods of determining direction. Various methods of determining direction are in use, as follows:

Watch method. When the sun is shining, direction can be determined with an ordinary watch. Hold the watch in such a position that the hour hand points to the sun. A line passing over the pivot of the hands halfway between the hour hand and the figure 12 of the dial will point approximately south.

The North Star. On a clear night the north can be approximately determined by the location of the North Star. Everyone should be sufficiently familiar with the stars to identify the North Star readily.

Short shadows. North can be determined when the sun is shining by means of a rod 20 to 30 inches long erected on a smooth place on the ground or on the top of a table set level. If the top of this rod is tapered to a point, a rather sharp shadow will be thrown. Shortly before twelve o'clock by the sun, the position of the point of the shadow should be marked with a small pin or toothpick. As the shadow continues to shorten, the points should be marked every few minutes. After a time the shadow will begin to lengthen and the markers will increase in distance from the base of the rod. A line from the base of the rod through the shortest marker will be north, and at the time the shortest marker is set it is twelve o'clock by the sun.

Equal arc. The north point can be determined by the equal-arc method by the same procedure as for short shadows. Approximately two or three hours before noon the point of the shadow should be carefully marked. With the distance from the base of the rod to this marker as a radius, describe a circle around the base of the rod. At about the same length of time after twelve o'clock as the marker was set before twelve, it will be found that the point of the shadow is approaching the circle from the inside. As the point crosses the circle it should again be marked. The distance between the two crossings on the circle should be bisected. A line from the base of the rod through this point is pointing north, and when the shadow of the point falls on this line the following day it is twelve o'clock by the sun. The error in getting the exact north point by either the short shadow or equal arcs is due to the fact that a shadow is not sharp and definite and it is impossible to determine correctly the exact shadow of the point. The method of equal arcs may be used approximately as a sun dial. After the shadow corresponding to several of the hours has been located, these shadows can be marked on the ground by means of small pieces of wood having the hour marked on them.

Compass. The universal method of determining north is by the use of the *magnetic compass.* Numerous explanations have been advanced for the action of the magnetic needle and reasons for its pointing in a given direction, but these explanations are not entirely satisfactory and will not be considered here. The part of the compass which gives direction is a slender bar of hard steel that has been magnetized and is free to rotate in a horizontal position. There is a popular belief that the needle always points to the north and is constant. This is not the actual condition. There are only a few places on the earth's surface where the needle points to the true north, and long observations have proved that the needle changes somewhat in its direction with the different hours of the day and with the different months of the year, and that there is a slight continuous change from year to year. Furthermore, it is very difficult to find two compasses that will point exactly in the same direction at the same time when set up under similar conditions. These differences are all small, and, with the exception of the one known as variation, they need not be taken into consideration.

There is an irregular line crossing the United States from the east end of Lake Superior, near Lansing, Michigan, Cincinnati, Ohio, and Savannah, Georgia, on which the needle points north. A compass west of this line points to the east of north, the variation increasing as the distance west is increased. At Seattle, Washington, the needle points 23° east of true north. As a compass is taken east of this line it points to west of north. At Augusta, Maine, it points 16° west of true north. When true direction is wanted, it is necessary to make correction for variation, which one can usually find by looking on land-survey maps, by sighting the compass along a section line, or by a magnetic chart.

Mariner's compass. The mariner's compass is one in which a card or similar light material is placed on top of the needle and swings with it. The directions are marked on this card and thus indicate the proper direction for following a given course. This make-up is most satisfactory for steering a vessel or for passing over lines in which the direction of travel is known.

Surveyor's compass. The surveyor's compass is one in which the letters indicating the directions are placed on a ring outside the needle, which is visible. The object of a surveyor's compass is to determine the direction of points that are not known. The fact that the east point is on the left side of the needle as it points north and the west point on the right side is confusing until it is clearly understood that the needle is the stationary object and the dial the moving part. By this arrangement of the east and west points the needle in the proper direction can always be read. In reading the compass, point the arrow on the dial directly at the object to which the desired direction is wanted. Then read the degrees under the north end of the needle, using the letters on either side of the north end. In correcting for variation, when the variation is east, add the variation to the reading when it is northeast or southwest, and subtract when it is northwest or southeast.

Compasses are on the market in many different forms and qualities. Some of them, for pocket use, are quite small. In buying a new compass the purchaser should fix definitely which is the north end of the needle and be sure he understands it thoroughly while working with known directions. To keep the compass in working order he should give attention to the following points: (1) The needle should be straight, well balanced, well magnetized, and the agate in good condition. (2) The point should be sharp and in the center of the box, so that the needle can swing without striking the sides. (3) In using a compass, keep it a sufficient distance from iron objects to prevent its being affected by them. One can usually determine this fact by moving around the iron object and noticing whether the needle is being turned toward the object.

Bearing. There are two kinds of bearing, magnetic and true. *Magnetic bearing* is the bearing of the line as indicated by the magnetic needle. *True bearing* is the bearing of the line after the magnetic bearing has been corrected for variation.

Exact determination. Exact determination of the true meridian requires careful observation of either the sun or the stars and laborious mathematical computations. Solar instruments are now in use which can be set up in such a position that they will give the north point with sufficient accuracy for surveying purposes whenever the sun is shining.

SUMMARY

Besides the measurements given in this chapter, others, such as horse-power, volts, and amperes, are discussed in connection with the subjects to which they particularly relate. There are many units of measure that have been purposely omitted because of the infrequency with which they are ordinarily encountered. The farmer would have little use for a knowledge of apothecary's weights or mariner's measure.

CHAPTER III[1]

ROPE

The ability to tie a few useful knots and splice a rope is of use not only to the sailor, but to the farmer, the construction engineer, and the contractor. Indeed, there are times when it is useful to people in nearly all walks of life.

Only a few knots, hitches, and splices are shown, as it is believed that the average person has not the time or persistence to learn a large number of them so thoroughly that he can make them at any time from memory. There are several ways of tying some knots and more than one way of making some of the splices and hitches, but only what is considered to be the best way is shown.

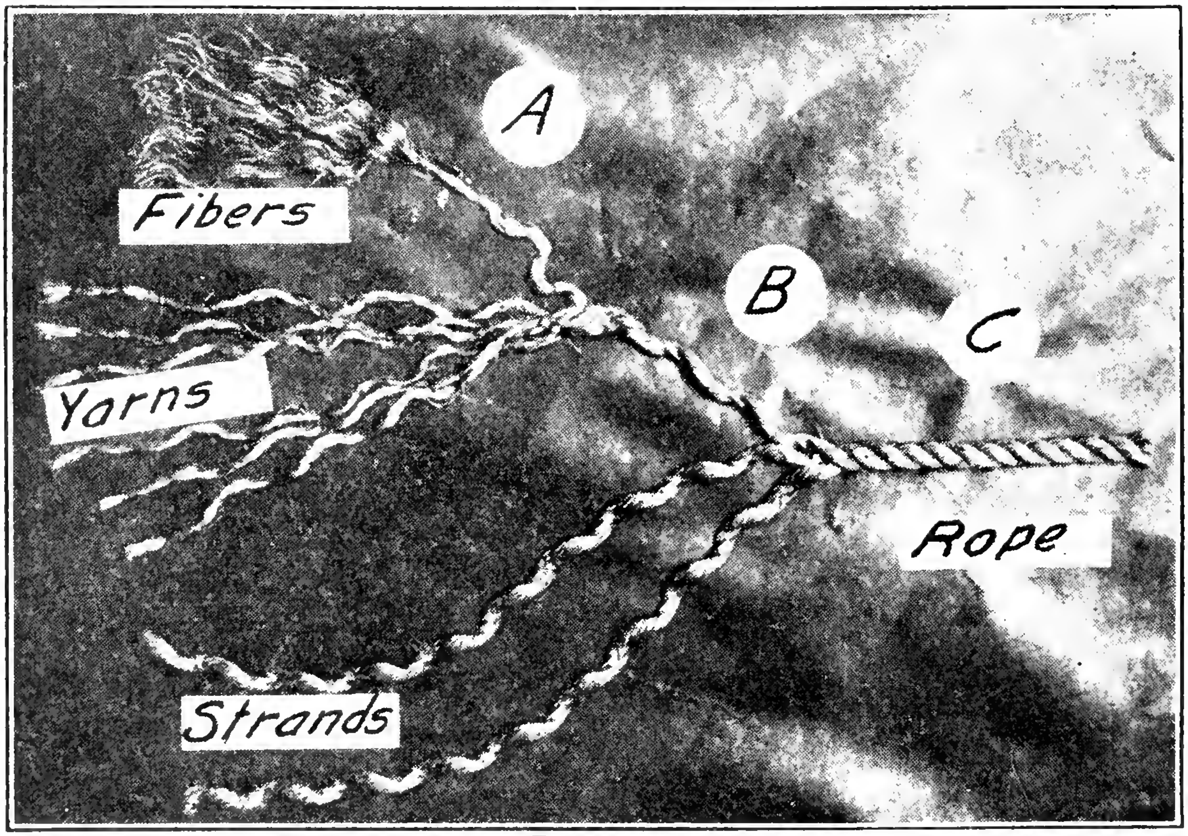

FIG. 7

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[1] After J. B. Frear, *Bulletin 136*, University Minnesota Agricultural Experiment Station.

Construction of rope. A rope is made of fibers so intertwined or twisted together as to form a thick cord capable of sustaining a severe strain. The primary object of twisting the fibers together to form a rope is that by friction they may be held together when a strain is applied to the whole. Hard twisting has the further advantage of compacting the fibers and preventing the penetration of moisture.

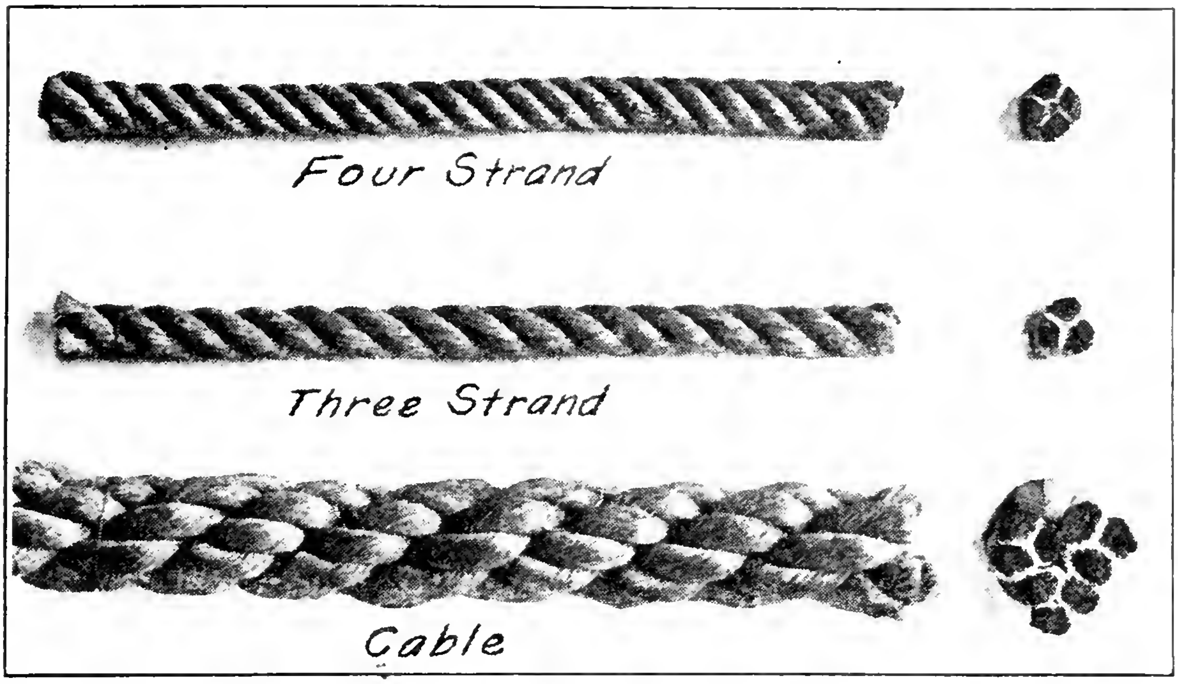

Fig. 8

The steps in the manufacture of rope are as follows:

1. The fibers are twisted into yarns in a direction called "right hand," as shown at *A* in Figure 7.

2. From two to eighty of these yarns are then twisted together into a strand in a direction called "left hand," as shown at *B* in Figure 7.

3. Three of these strands for a three-strand, and four for a four-strand rope are then twisted together in a direction called "right hand," as shown at *C* in Figure 7.

4. If these ropes are twisted together to form a cable, shown in Figure 8, they are twisted in a direction called "left hand."

When a strand is twisted up, the yarns composing it are untwisted; and when a rope is twisted up, the strands composing it are untwisted, but the yarns in the strands are again twisted up. It is this opposite twist that keeps the rope from untwisting. When a weight is hung at the end of a rope, the tendency is for the rope to untwist and become longer. The weight will revolve until the strain of the rope trying to untwist is just balanced by the strain of the strands being twisted up. All makers of rope twist them in the same direction; otherwise it would not always be possible to splice ropes obtained from the different factories.

Sources of fiber. Many different vegetable fibers are used for rope making. The most common ones are Manila, or Manila hemp, common hemp, sisal hemp, and cotton. Flax, jute, coir fiber, and other materials are also used.

Manila fiber is obtained from the abacá plant, which grows only in the Philippine Islands. It obtains its name from the city of Manila, from which most of it is exported. The trunk of this plant resembles the banana tree and is closely wrapped by long leaves which yield fibers from 6 to 12, and even 18, feet in length.

Common hemp is an annual herb of the nettle family, from 4 to 8 feet high. It has green flowers and a tough, fibrous inner bark. The tough, strong fibers obtained from the inner bark are used in making coarse cloth and rope.

Sisal hemp comes principally from Yucatan and Mexico. Its fiber is especially valuable for ship cables, as it seems to resist the action of sea water better than most other materials.

Cotton is planted annually in the United States and is the staple agricultural product of our southern states. The commercial cotton is the soft, woolly, fibrous material which is attached to the seeds of the cotton plant. The fiber is white or yellow, and from two-thirds of an inch or less to 2 inches long. The fibers are contained in a three- to five-celled capsule or boll which bursts open when ripe and allows the fibers to escape. After the seeds are removed, the fiber is manufactured into thread, cloth, twine, and rope.

Flax is an annual plant with stems about 2 feet high, blue flowers, and a fibrous inner bark which yields the flax of commerce.

Jute is obtained from two tall, slender-stemmed, annual Asiatic herbs of the linden family, now naturalized in various countries. The fiber obtained from the inner bark is used in the manufacture of carpets, bagging, canvas mats, and rope.

Coir fiber, which is obtained from the husk of the coconut, is an important factor used for rope making and cordage. It is fairly strong and is lighter than Manila or hemp.

How sold. Rope is usually retailed by weight, but is ordered by giving the diameter in inches and number of feet wanted. Wholesale dealers sell it by the weight stamped on the coils by the manufacturer, but do not usually break the coils.

Strength of rope. The strength of a new rope of a given size will depend on (1) the kind of fiber used, (2) the quality of the fiber, (3) the quality of the workmanship, (4) the effect of preservatives on the fibers, and (5) the number of strands. No accurate rule can be given for calculating the strength, and any table giving the strength will be only approximately correct. Four-strand ropes have about 16 per cent more strength than three-strand ropes. Tarring rope decreases the strength by about 25 per cent because the high temperature of the tar injures the fibers. The strength of a rope is decreased by age, exposure, and wear.

The breaking strength of a rope is the weight or pull that will break it. The safe load is the weight you may put on a rope without danger of breaking it. The safe load must be very much less than the breaking strength, in order that life and property may not be endangered when heavy objects are being moved and lifted. The safe load is usually regarded as one-sixth of the breaking strength. The breaking strength and safe load for old ropes must be largely a matter of good judgment and experience.

Calculation of strength. For new Manila rope the breaking strength in pounds may be found approximately by the following rule: Square the diameter, measured in inches, and multiply this product by 7,200. Results obtained from this rule may vary as much as 15 per cent from actual tests. The safe load can be found by dividing the breaking strength by 6.

Suppose we wish to find the breaking strength and safe load of a ¾-inch Manila rope. The square of ¾ is 9/16, which, multiplied by 7,200, gives 4,050 pounds as its breaking strength, and 4,050 divided by 6 gives 675 pounds as its safe load.

Hemp rope is approximately three-fourths as strong as Manila, so that we use the following rule for it: The breaking strength of hemp rope in pounds is 5,400 times the square of the diameter in inches. The safe load is found by dividing the breaking strength by 6 as we did for the Manila rope. Thus breaking strength for a ¾-inch hemp rope would be

$$\tfrac{3}{4} \times \tfrac{3}{4} \times 5400 = 3037.5 \text{ pounds,}$$

and the estimated safe load would be

$$3037.5 \div 6 = 506.25 \text{ pounds.}$$

Calculation of weight. One rule for calculating the weight of rope is the following: To find the weight of a piece of rope 1 foot long, square the diameter measured in inches, and multiply this number by 0.32. Results obtained by this rule may vary as much as 10 per cent from the actual weight of new rope. Rope will take up moisture if stored in damp places, as basements, so that its weight will be considerably increased.

The actual diameter of rope is usually a little larger than the figures given in the table. The circumference is given to the nearest eighth of an inch. The number of feet in a coil may vary from the figures given in the table. Nearly all sizes are now put up in half coils also. The weight per coil will vary with the number of feet and the quantity of moisture contained in the rope. The weight of coils of new rope of equal length as received from the factory may vary as much as 15 per cent from the weights given in the table. The actual weights and lengths may vary as much as 10 per cent, because of differences in hardness of twist and moisture content. The figures for the breaking strength of hemp are approximately three-fourths of the values given for Manila. The safe loads are approximately one-sixth of the breaking strengths.

INFORMATION ABOUT THREE-STRAND UNTARRED ROPE

DIAMETER	CIRCUMFERENCE	FEET PER COIL	WEIGHT PER COIL	WEIGHT PER 100 FT.	FEET PER POUND	BREAKING STRENGTH		SAFE LOAD	
						Manila	Hemp	Manila	Hemp
In.	In.		Lb.	Lb.		Lb.	Lb.	Lb.	Lb.
3/16	9/16	2,400	40	1 2/3	60	240	180	40	30
1/4	3/4	2,400	55	2 1/2	43	450	330	75	55
5/16	1	2,400	70	3	32	720	540	120	90
3/8	1 1/8	1,200	45	4 1/4	23 1/2	1,070	810	180	135
1/2	1 1/2	1,200	90	7 1/2	13 1/2	1,800	1,350	300	225
5/8	2	1,200	170	13 1/2	7 1/3	3,000	2,340	500	390
3/4	2 3/8	1,200	210	17	6	3,900	2,940	650	490
7/8	2 3/4	1,200	295	25	4	5,520	4,140	920	690
1	3 1/8	1,200	340	30	3 1/3	6,900	5,160	1,150	860
1 1/8	3 1/2	1,200	455	40	2 1/2	8,850	6,640	1,475	1,100
1 1/4	3 7/8	1,200	510	45	2 1/4	10,800	7,950	1,800	1,325
1 1/2	4 3/4	1,200	785	70	1 1/2	15,000	11,400	2,500	1,900
1 3/4	5 1/2	1,200	1,160	100	1	20,640	15,600	3,440	2,600
2	6 1/4	1,200	1,440	125	5/6	24,660	18,600	4,110	3,100

Care of rope. Keep rope in a dry place, do not leave it out in the rain. If a rope gets wet, stretch it out straight to dry. Do not let the ends become untwisted, but fasten them in some way to prevent untwisting as soon as the rope is obtained. A stiff and hard rope may be made very soft and flexible by being boiled for a time in pure water. This will of course remove some of the tar or other preservatives. Cowboys treat their lasso ropes in this way.

Uncoiling rope. 1. Start with the end found in the center of the coil as shown in Figure 9.

2. Pull this end out and the rope should uncoil in a direction opposite to the direction of motion of the hands of a clock as shown by the arrow in Figure 9.

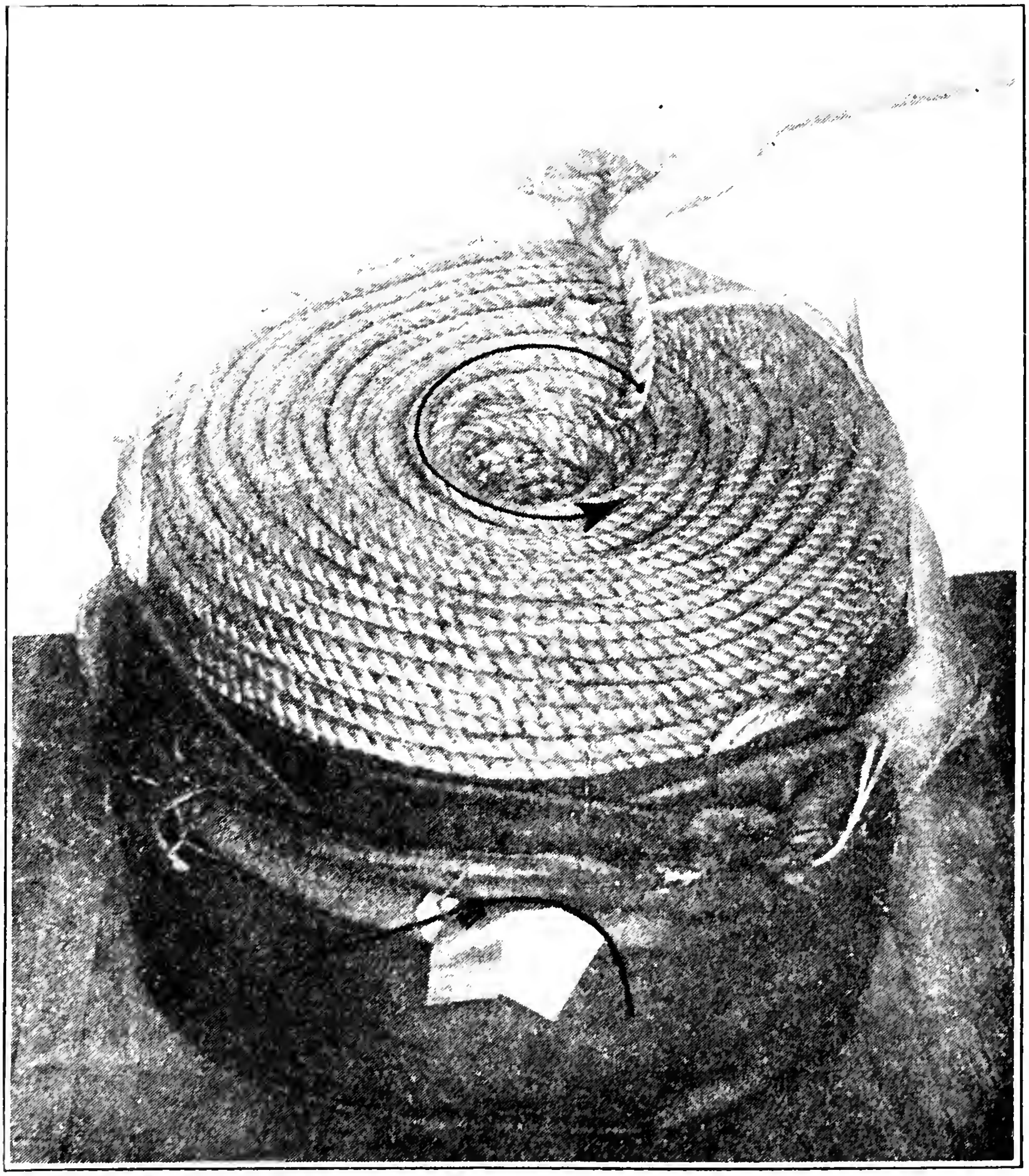

FIG. 9

3. If it uncoils in the wrong direction, turn the coil over and pull this same end through the center of the coil and out on the other side.

4. If these directions are followed, the rope will come out of the coil with very few kinks or snarls.

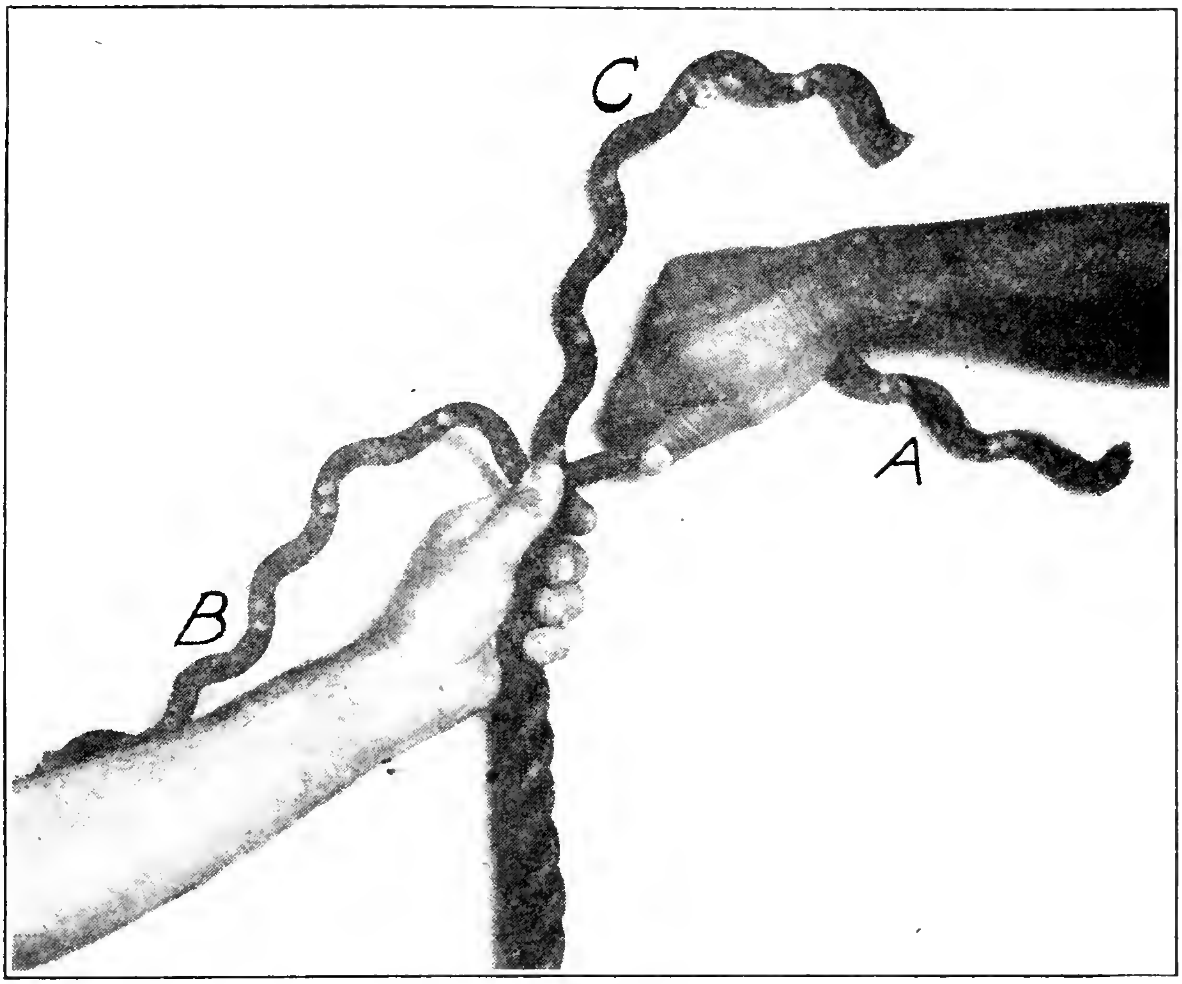

FIG. 10

Relaying an untwisted rope. Knowing how to relay the strands is useful because it enables you to save a part of the strands that would otherwise have to be cut off and wasted. In relaying do not twist or turn the rope, but twist each strand up tight and lay it in its proper place as shown by strand *A* in Figure 10, holding it with the thumb. Strand *B* is next put in place, then strand *C*, and then strand *A* again.

Principles of a knot. A knot or hitch should be so tied that two adjacent parts of the rope cannot move in the same direction, and the free end should be firmly held by a tight part of the rope against another tight part or against the object to which the rope is fastened.

Elements of a knot. The open bight, shown in Figure 11, the bight, Figure 12, and the round turn, shown in Figure 13, are elements that are used in making knots, hitches, and splices.

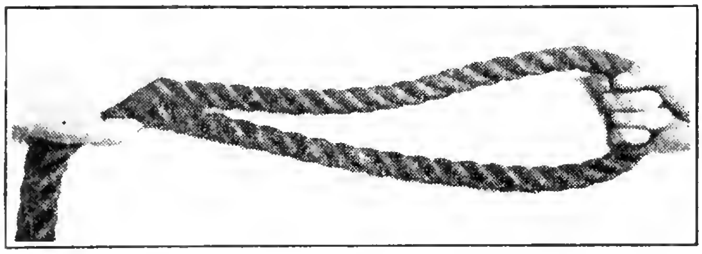

FIG. 11

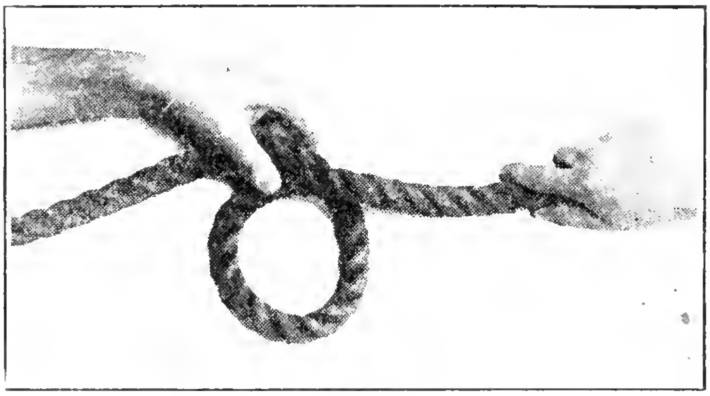

FIG. 12

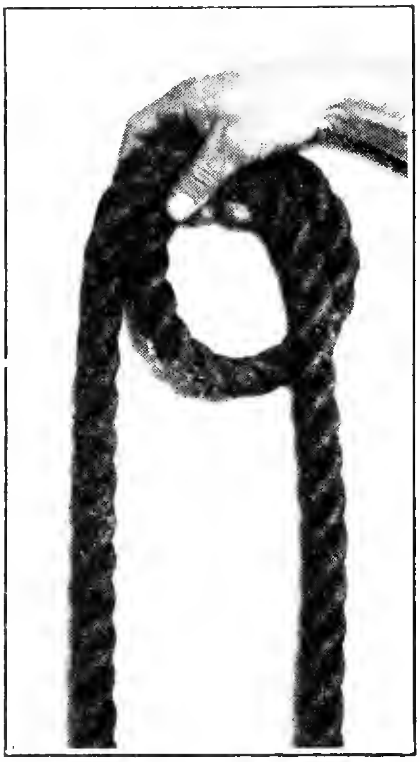

FIG. 13

PREVENTING THE ENDS OF ROPE FROM UNTWISTING

Whipping. Whipping should be used wherever the end of the rope must pass through small openings, as in reeving a set of blocks. In whipping, carefully observe these directions:

1. Put a string under a strand of the rope at a distance from the end which is equal to a turn of one strand, as shown in Figure 14 and allow several inches of end, as shown at *A* in Figure 14.

2. Give the end *B* one turn around the rope as shown by the arrow in Figure 14, and then fold the end *A* over as shown in Figure 15.

3. Continue whipping or wrapping the end *B* tightly around the rope and end *A* until you have reached a point

about midway between the starting point and the end of the rope, as shown in Figure 16.

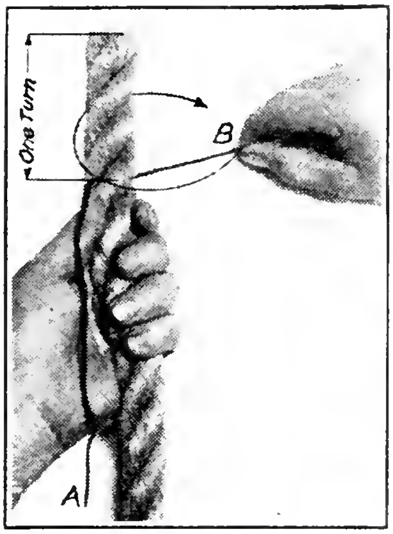

FIG. 14

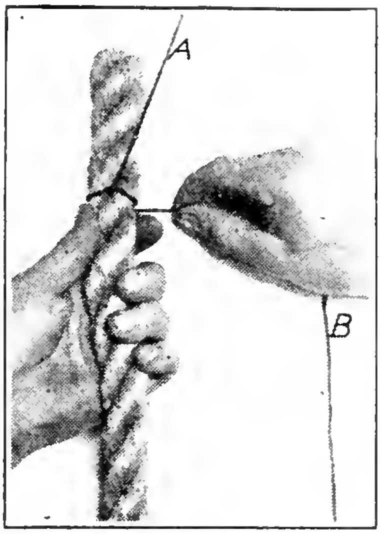

FIG. 15

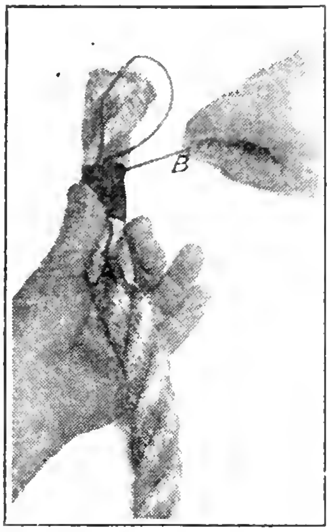

FIG. 16

4. Fold the end *A* back, making a loop that will reach slightly beyond the end of the rope as shown in Figure 16.

5. Continue whipping the end *B* around the rope outside the loop, which should be laid in the groove formed by two strands, until the work appears as shown in Figure 17.

6. Pass end *B* through the loop, then pull end *A* until it draws the end *B* under the whipping as far as possible, and cut both ends off very close. The completed work should appear as shown in Figure 18.

FIG. 17

FIG. 18

Wall knot with crown. The wall knot with crown is used for the ends of halter ropes, etc., and to prevent the rope from pulling through a small opening, as in case of the rope handles of a chest. The wall knot alone is made as described on page 38.

1. Unlay the end of the rope about three turns and spread the strands out, having No. 3 back of the other two, as shown in Figures 19 and 20.

2. Move the end of strand 1 as shown by the arrow in Figure 19 and form a bight as shown in Figure 20.

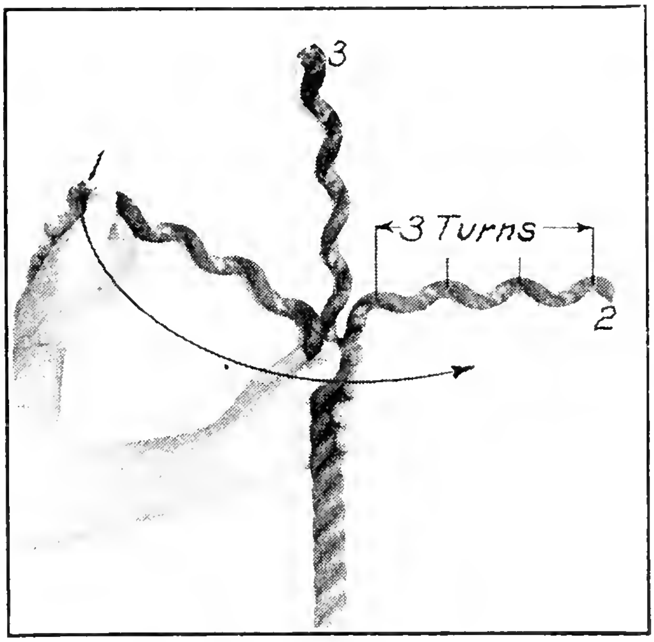

FIG. 19

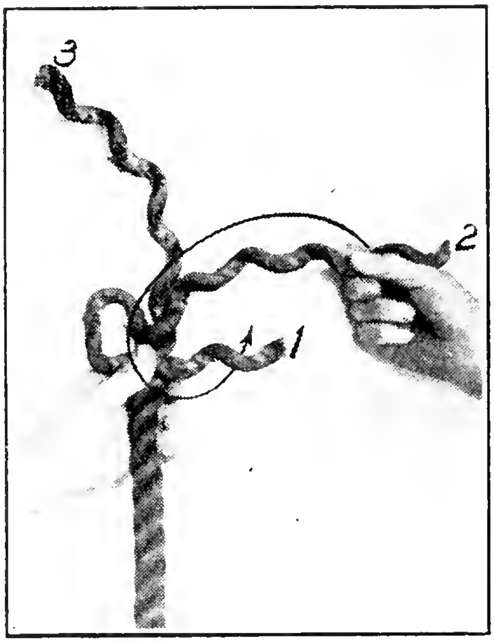

FIG. 20

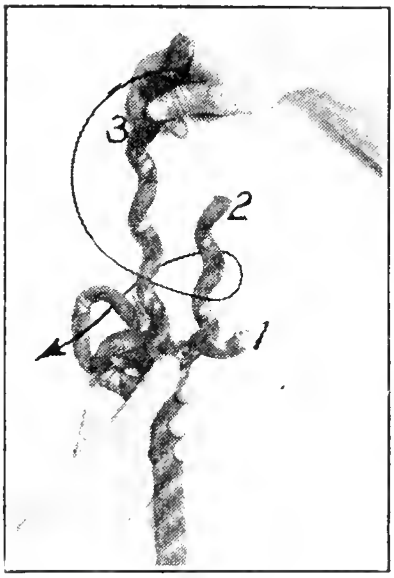

FIG. 21

FIG. 22

3. Move the end of strand 2 as shown by the arrow in Figure 20 and form a bight around the end of strand 1 as in Figure 21.

4. Move the end of strand 3 as shown by the arrow in Figure 21, forming a bight around the end of strand 2 and passing the end of 3 through the first bight in the right direction. The work should now appear as in Figure 22.

5. Draw the knot up tight by pulling the strands at right angles to the rope, as shown in Figure 23.

The knot without the crown is shown in Figure 24, but must be crowned, as shown in Figures 25–29.

1. Hold the rope as shown in Figure 25.

2. Move the end of strand 1 as shown by the arrow in Figure 25, forming an open bight, as shown in Figure 26 on page 40.

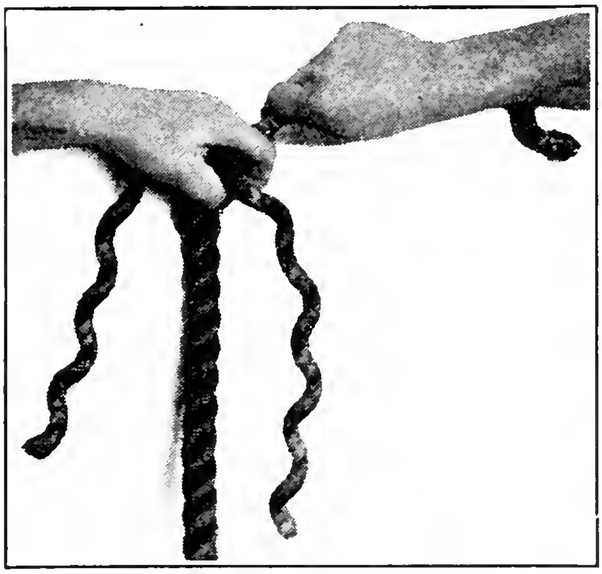

FIG. 23

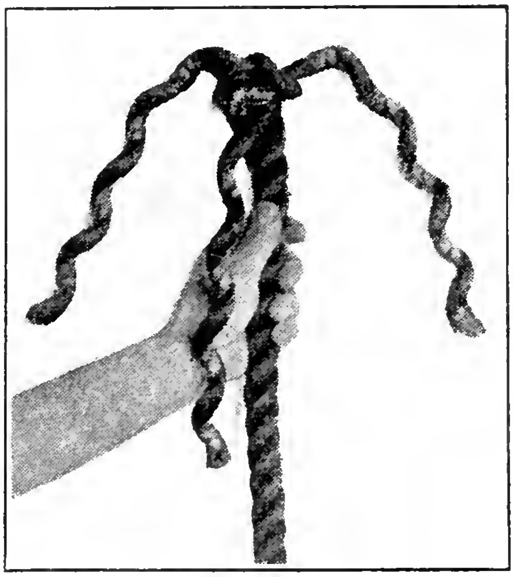

FIG. 24

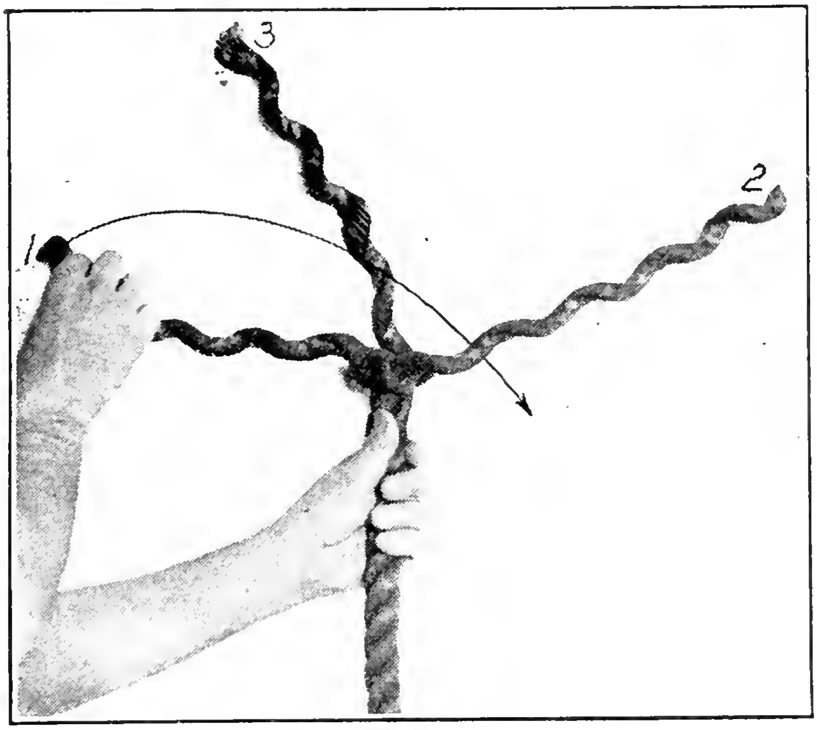

FIG. 25

3. Move the end of strand 2 as shown by the arrow in Figure 26, passing it between the bight and strand 3 and drawing it down tight as shown in Figure 27.

4. Move the end of strand 3 as shown by the arrow in Figure 27, being sure that the bight stands up straight when you pass the end of strand 3 through it, as shown in Figure 28.

5. Draw the strands up tight, starting with strand 1, and the finished work should appear as shown in Figure 29, except that the ends should be cut off quite short. It is a good plan to wet the strands, as they will hold their position better when drawn up.

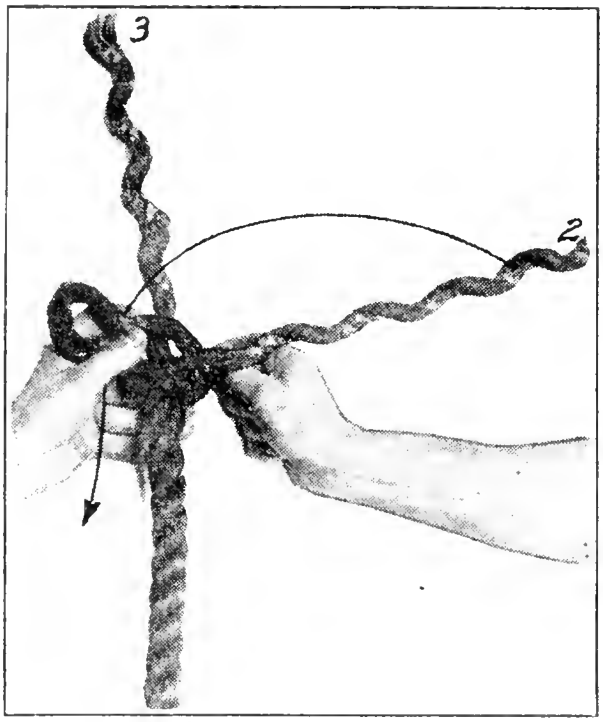

FIG. 26

FIG. 27

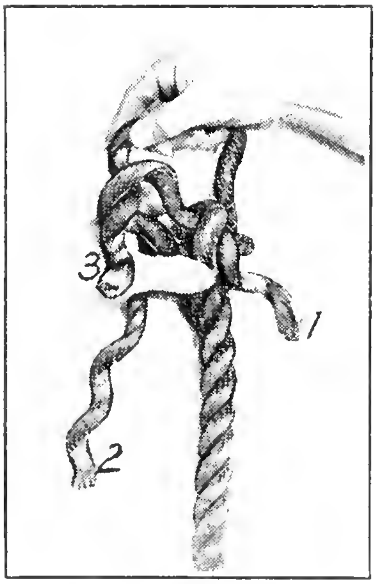

FIG. 28

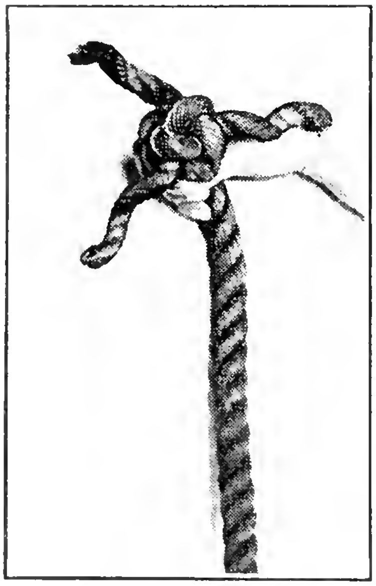

FIG. 29

KNOTS FOR TYING ROPES TOGETHER

Square knot. The square knot is used for tying ropes securely together, but will draw rather tight, especially with small ropes. It is a good knot for tying binder twine together. One rope has been dyed black in order that the illustrations may be clearer. The knot may be tied by observation of the illustrations and directions.

1. Cross the ropes with the proper one nearest you as is shown in Figure 30.

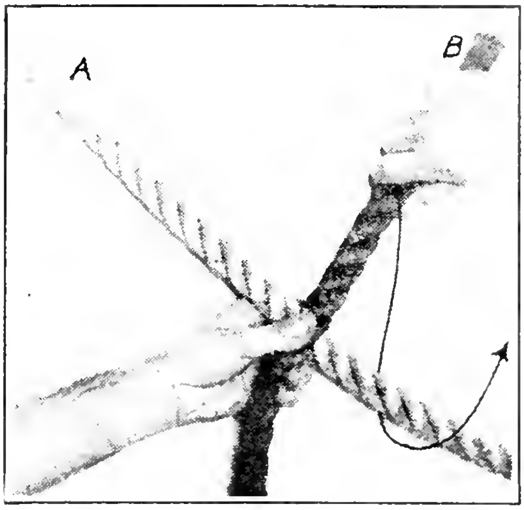

Fig. 30

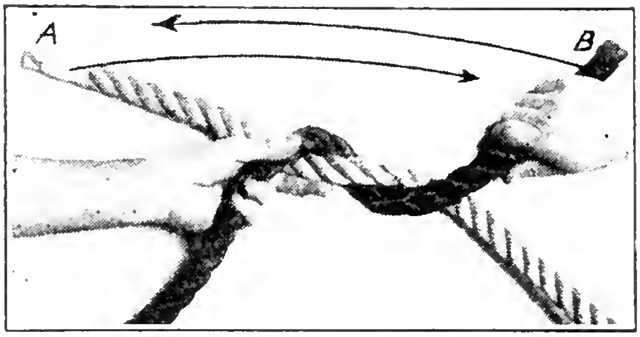

Fig. 31

2. Move end *B* as shown by the arrow in Figure 30 until it is in the position shown in Figure 31.

3. Move ends *A* and *B* as shown by the arrows in Figure 31 until they are in the position shown in Figure 32. Be sure the proper end is nearest you at the point of crossing in the right hand.

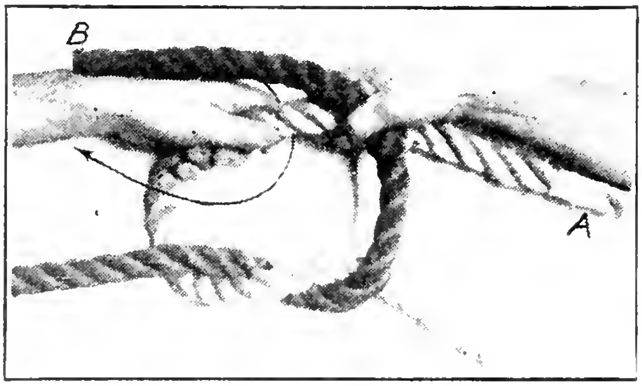

Fig. 32

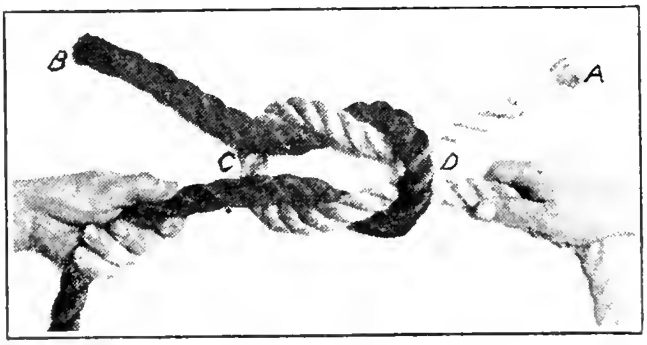

Fig. 33

4. Move end *B* as shown by the arrow in Figure 32 until it is in the position shown in Figure 33, and draw up tight. Both parts of one rope should be in front of or behind the other, as shown at points *C* and *D* in Figure 33.

Weaver's knot. The weaver's knot obtains its name from the textile mills, where it is used to tie threads together.

It is better than the square knot for tying straps together. The weaver's knot may be made as described below and on page 43.

1. Hold the ends of the rope as shown in Figure 34.

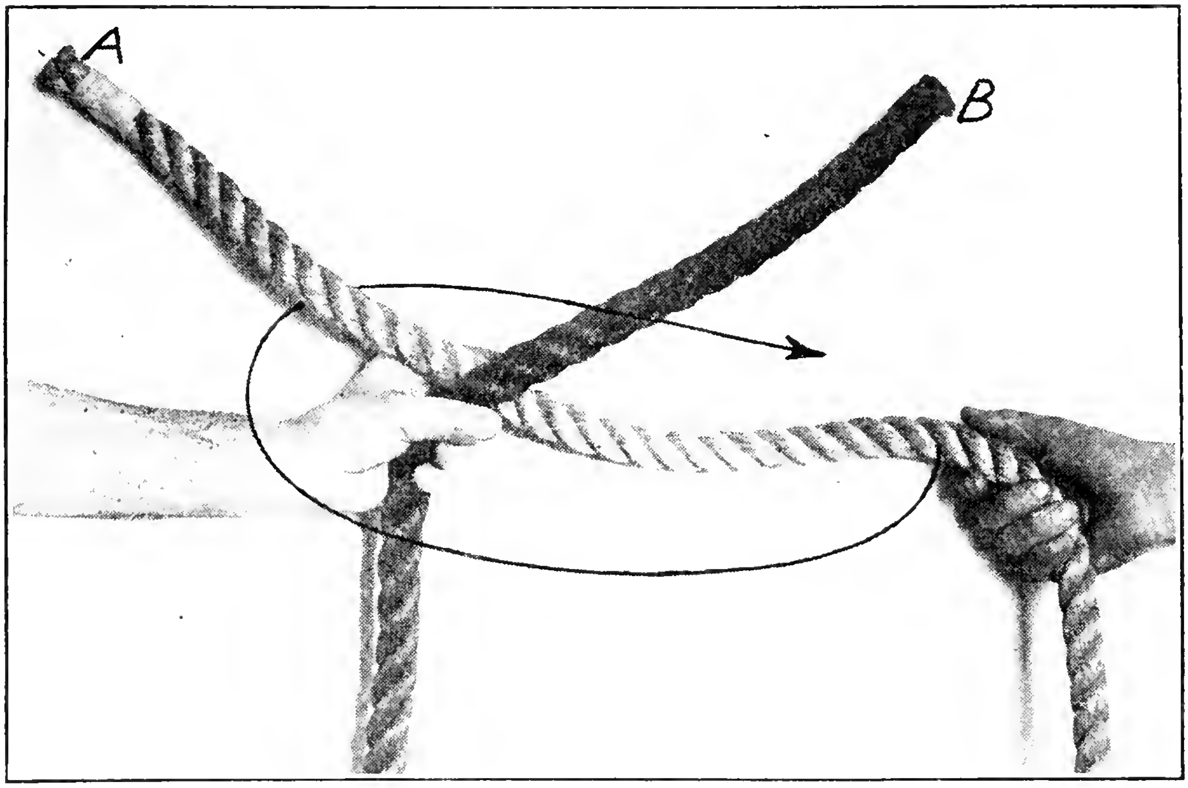

FIG. 34

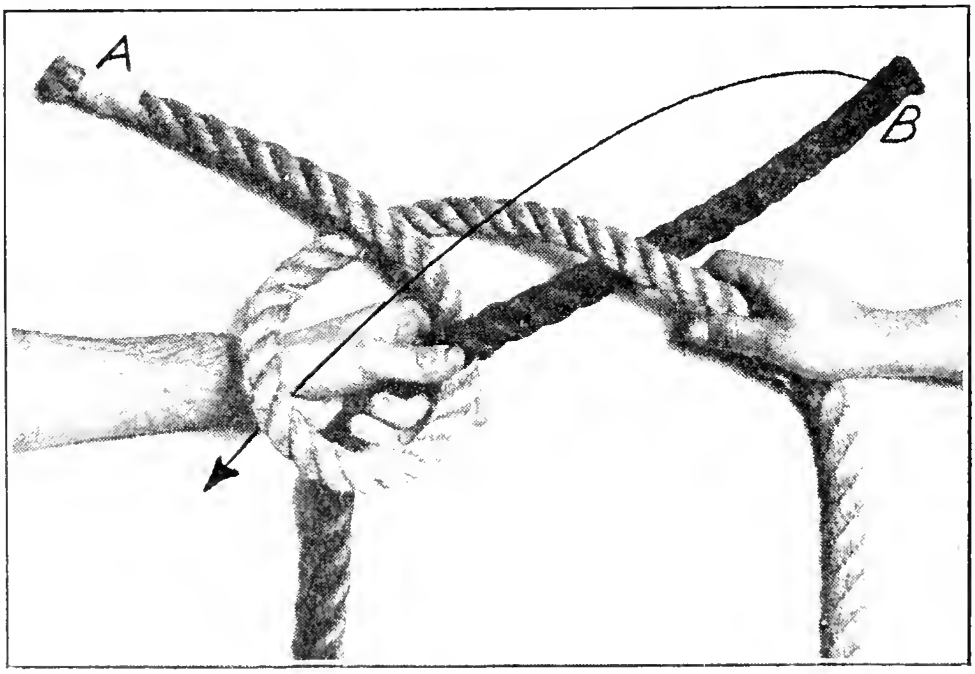

FIG. 35

2. Move right hand in the direction shown by arrow in Figure 34 until the rope is in position shown in Figure 35.

3. Grasp end *B* with the right hand, then move it in the direction shown by the arrow in Figure 35 and hold it with the left hand as shown in Figure 36.

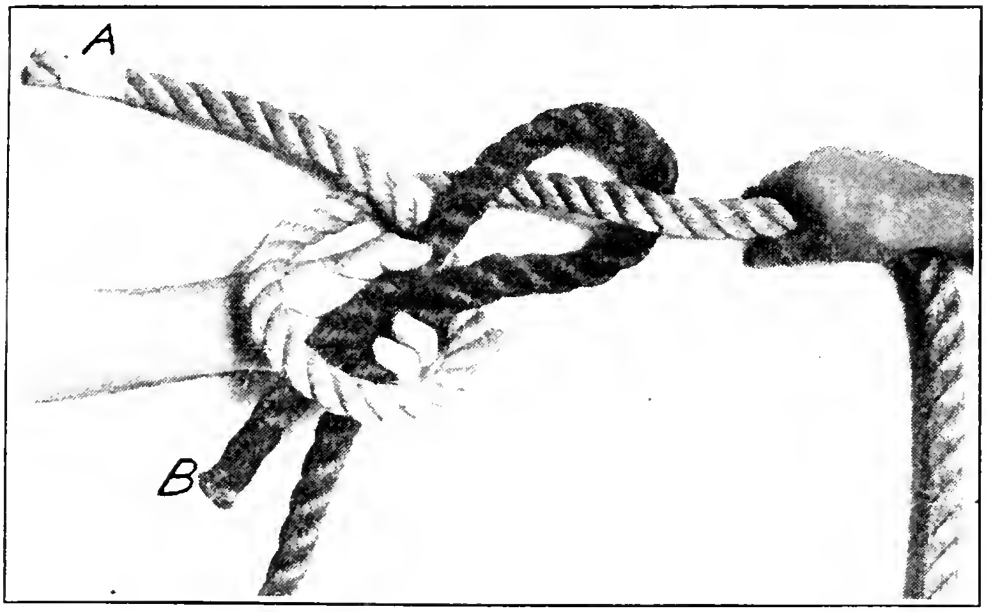

FIG. 36

4. Draw the knot tight by pulling the hands apart, when it should appear as shown in Figure 37.

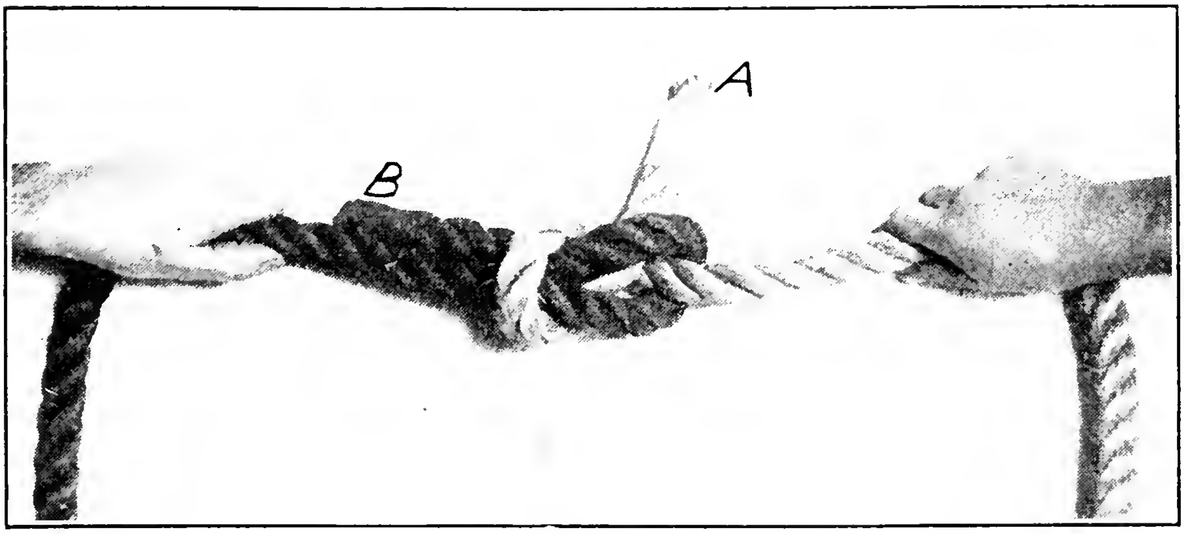

FIG. 37

LOOPS AT THE ROPE'S END

Bowline. The bowline is sometimes called the king of knots. It is used wherever a loop is wanted that will not slip or pull tight. It can always be untied very easily and is tied as described on page 44.

1. Hold a bight with the short end nearest you at the point of crossing and pass the end *A* through any opening or around any object, as shown in Figure 38.

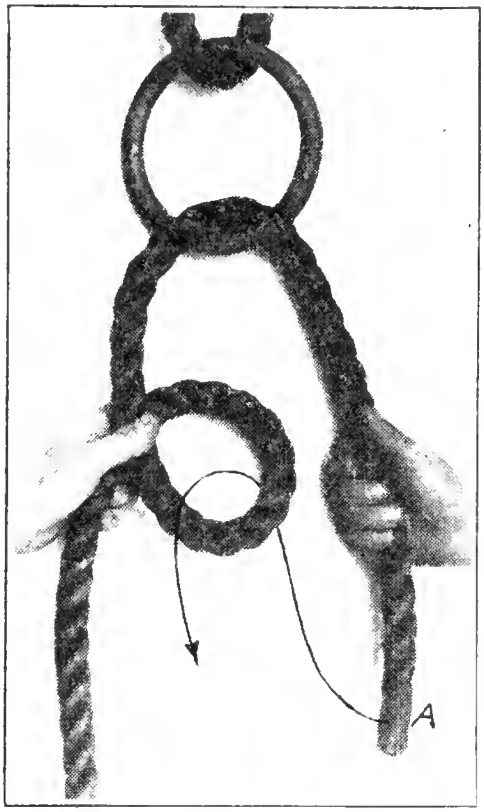

FIG. 38

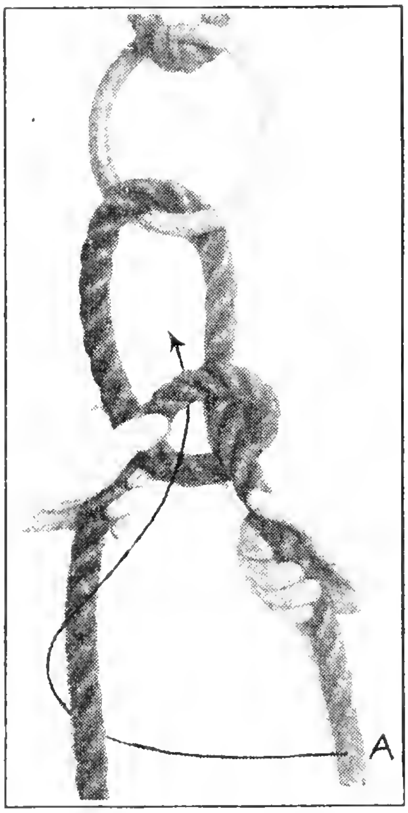

FIG. 39

FIG. 40

FIG. 41

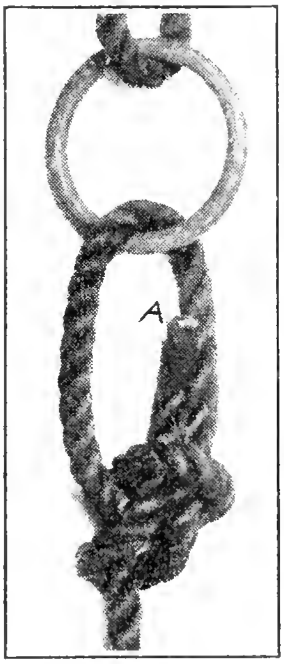

FIG. 42

2. Pass the end through the bight in the proper direction, as shown by the arrow in Figure 38.

3. Move end *A* as shown by the arrow in Figure 39 until it is in the position shown in Figure 40.

4. Grasp the end *A* and the right side of the loop as shown in Figure 41 and draw the long end until the knot becomes tight, as shown in Figure 42.

Slip knot. The slip knot is used when a loop is wanted that will slip up tight around an object. There are four steps in tying it:

1. Hold the rope as shown in Figure 43.

2. Move the right hand so that point *A* moves as shown by the arrow in Figure 43, thus forming a round turn in the left hand as shown in Figure 44, and allow the right hand to slip on the rope to point *B*.

3. Move the right hand so that point *B* moves as shown by the arrow in Figure 44 to the position shown in Figure 45.

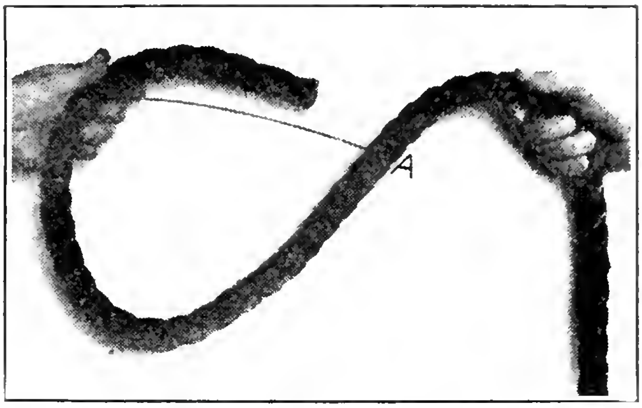

FIG. 43

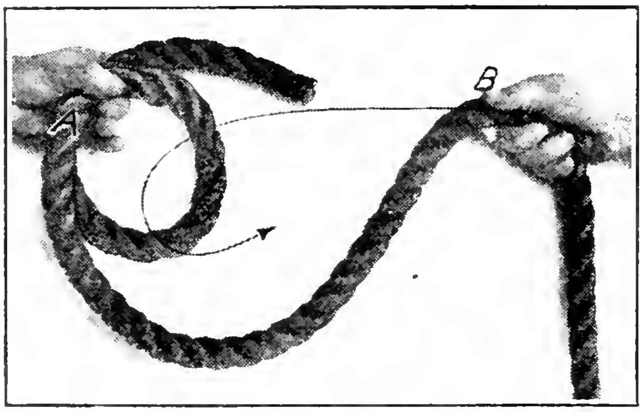

FIG. 44

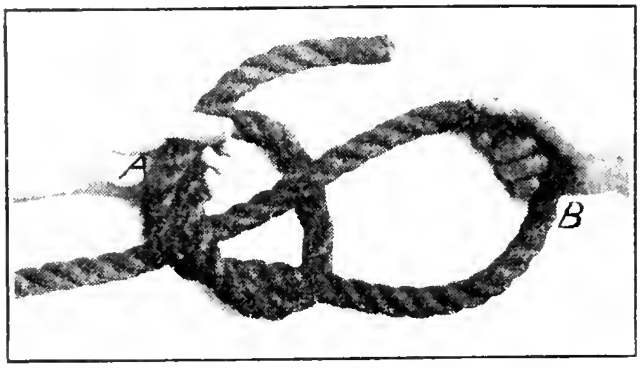

FIG. 45

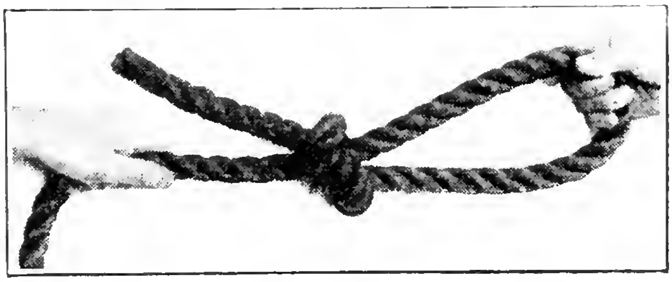

FIG. 46

4. Draw the overhand knot that has been formed up tight, and the finished knot should appear as shown in Figure 46.

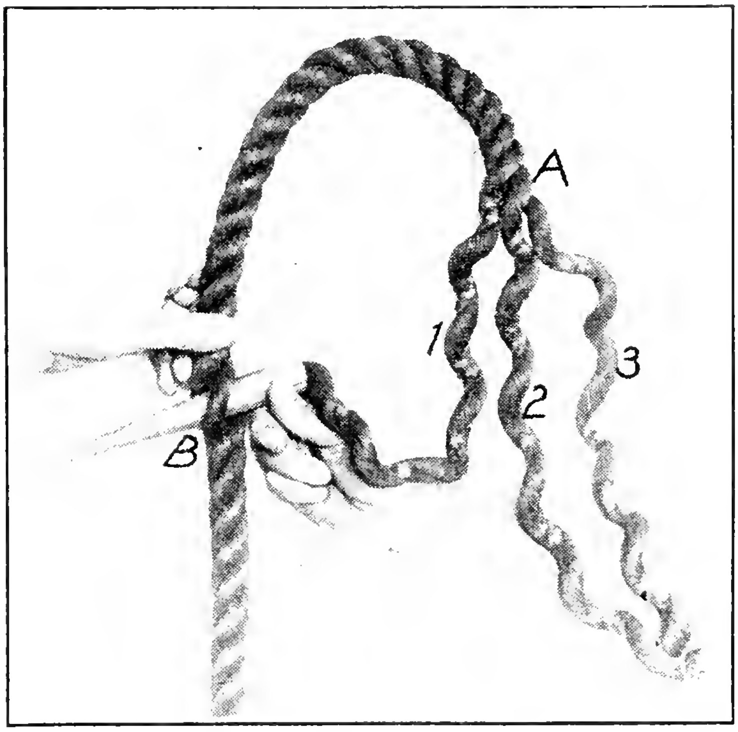

FIG. 47

Spliced eye. The spliced eye is used to fasten a rope permanently into a ring or eye, or to make a permanent loop at the end of a rope. The same method may be used for splicing one rope into the side of another. Learn to make the short splice (page 50) before trying to make the spliced eye, then follow these directions:

1. Unlay the strands about five turns, and start strand 1 under any strand as shown at point *B* in Figure 47. The distance from *A* to *B* should be enough to make an eye of the desired size.

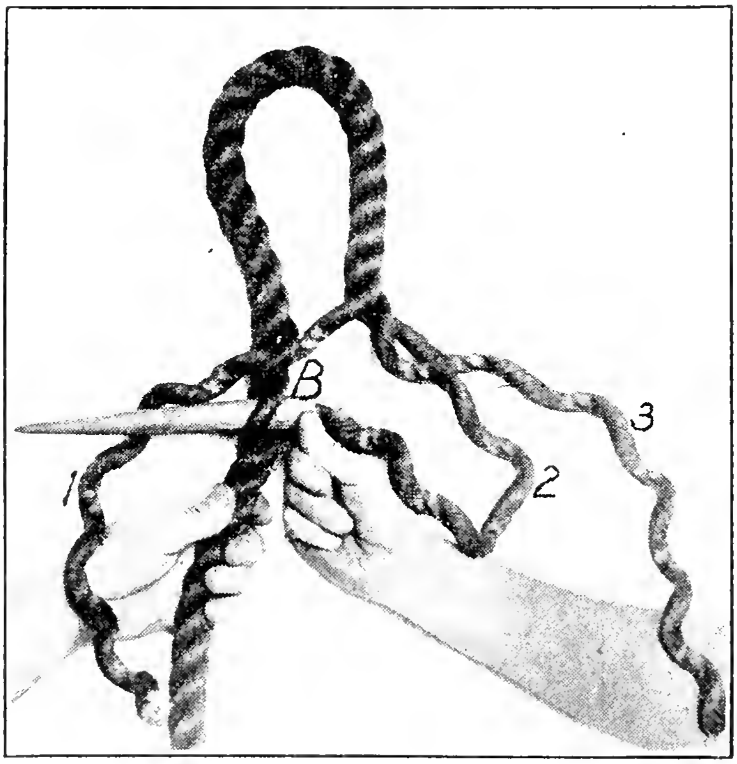

FIG. 48

2. Draw strand 1 through the rope and start strand 2 under the next strand at point *B* as shown in Figure 48. Be sure not to get strand 3 in the place of strand 2.

3. Pass strand 3 under the next strand at point *B* as shown in Figure 49.

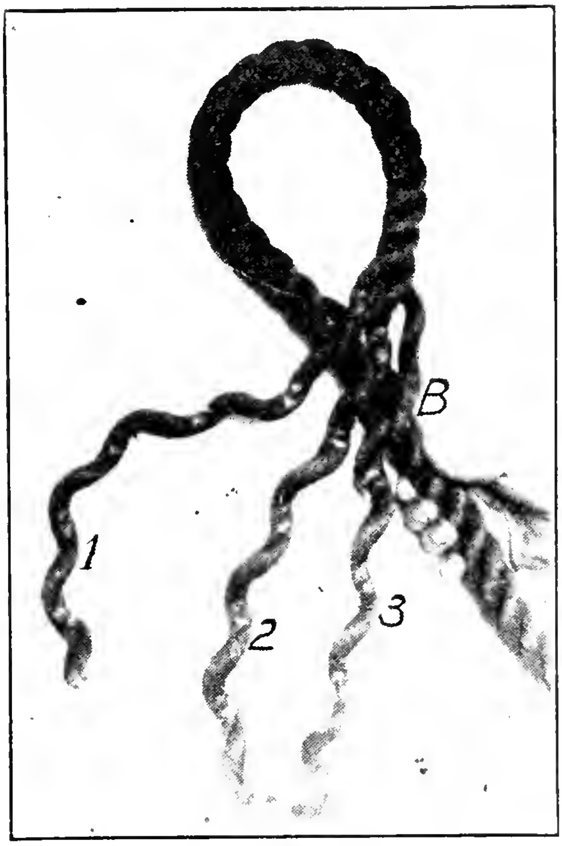

Fig. 49

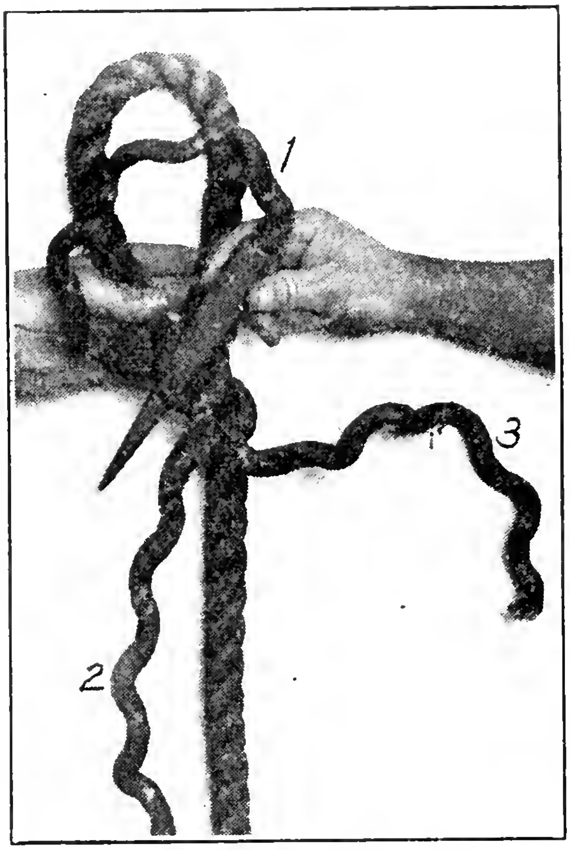

Fig. 50

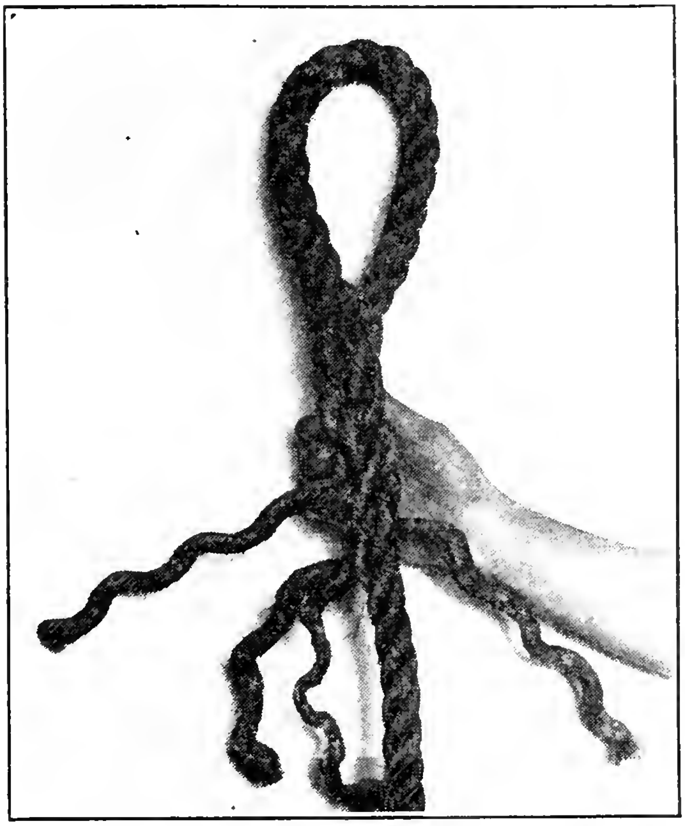

Fig. 51

Fig. 52

4. Draw the three strands up tight and splice them into the rope just as you do in making the short splice. The remainder of the work is shown in Figures 50, 51, and 52.

FIG. 53

FIG. 54

HITCHES AND TIES

Half hitch. In Figure 53 the short end of the rope is half hitched around the other part.

Timber hitch. The timber hitch is used for dragging and lifting logs and timbers, and is shown in Figure 54. To make it, take a half hitch and then give the short end one turn around the rope.

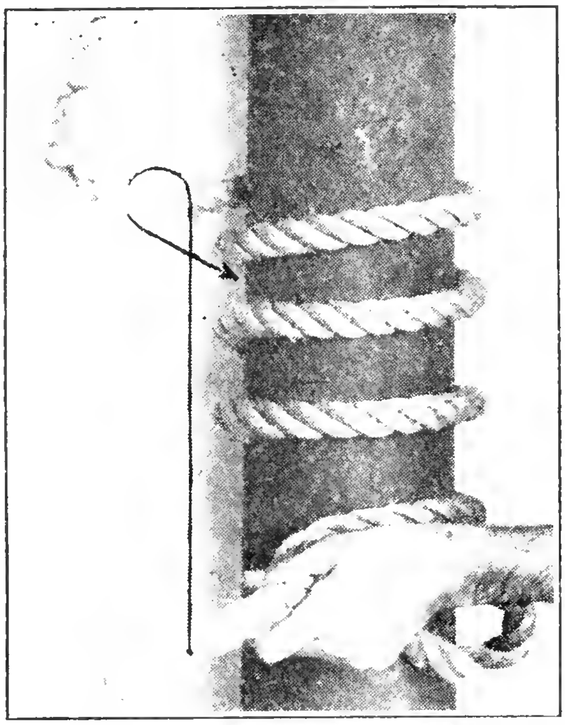

FIG. 55

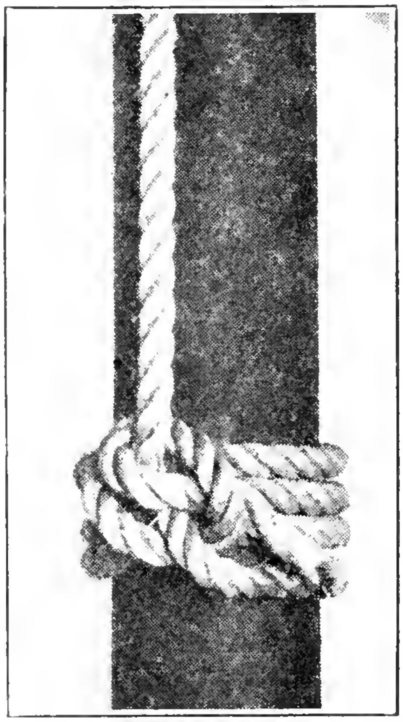

FIG. 56

Well-pipe hitches. Well-pipe hitches are used to pull a well pipe or lift a similar object.

1. Give the rope four turns around the pipe as shown in Figure 55.

2. Give the short end of the rope two half hitches around

the long end, making the first half hitch as shown by the arrow in Figure 55, and the second one between the first one and the left hand.

3. Slide the turns and hitches tight together as shown in Figure 56 and pull on the long end.

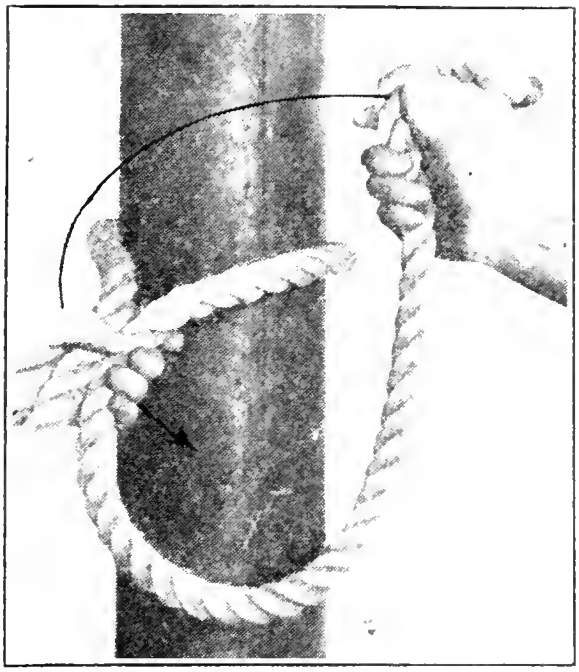

FIG. 57

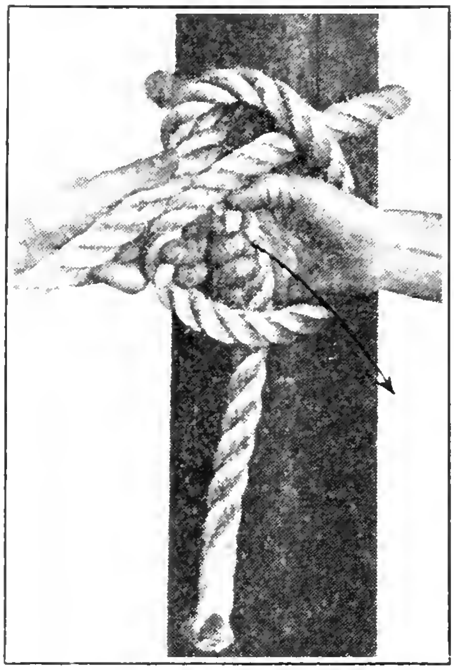

FIG. 58

Halter ties. Halter ties are used to fasten halter or hitching ropes to posts or rings, and the bow-and-slipknot type may be made as follows:

1. Hold the rope as shown in Figure 57.

2. Move the right hand in the direction shown by the arrow in Figure 57 and place the rope in the position shown in Figure 58.

3. Pull the short end partly through the bight thus formed and draw the knots tight.

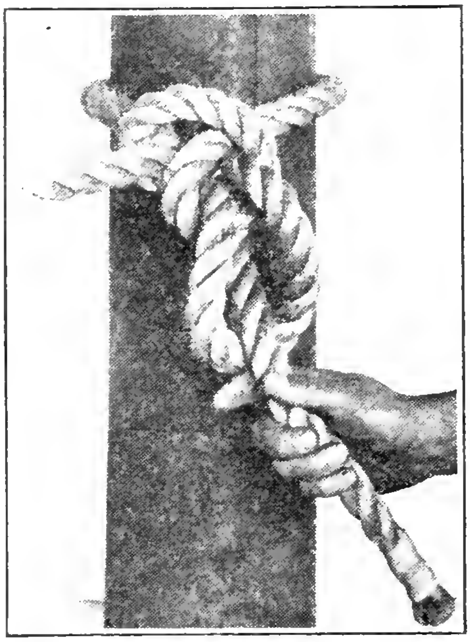

FIG. 59

4. Pass the short end through the last loop formed as shown in Figure 59. This knot is very easily made, holds securely, and is easily untied.

SPLICES

Short splice. The short splice is used to fasten two pieces of rope together securely, but should not be used where the splice must run over sheaves or pulleys. In making the short splice with three-strand rope observe the following directions:

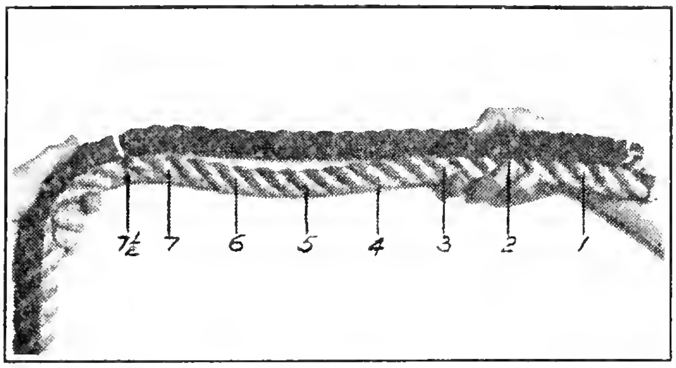

Fig. 60

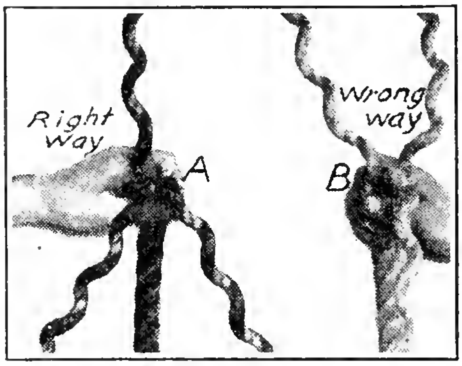

Fig. 61

1. Count off seven and a half turns from the ends to be spliced and tie strings around the ropes at the points thus found, as shown in Figure 60.

2. Unlay the ends back to the strings and open each end as shown at *A* in Figure 61. The end shown at *B*, Figure 61, is not opened in the right way. No strand should pass between the other two. Be sure to have both ends opened as the one at *A*, for if you do not the splice will never be correct.

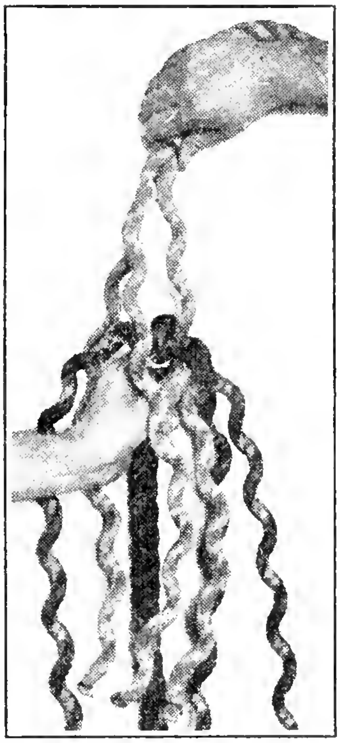

Fig. 62

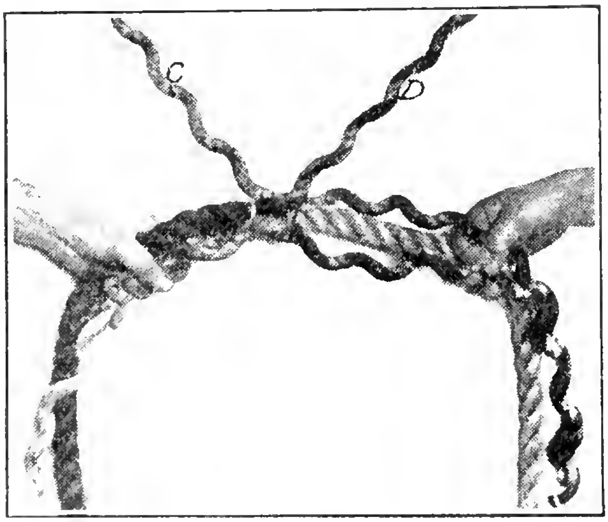

Fig. 63

3. Put the two ends together as shown in Figures 62 and 63, being sure to have a strand from one end between two strands from the other end. We now have three pairs of strands, *C* and *D* forming one pair.

Have the strand *D* from the left-hand rope between yourself and *C* as shown in Figure 63.

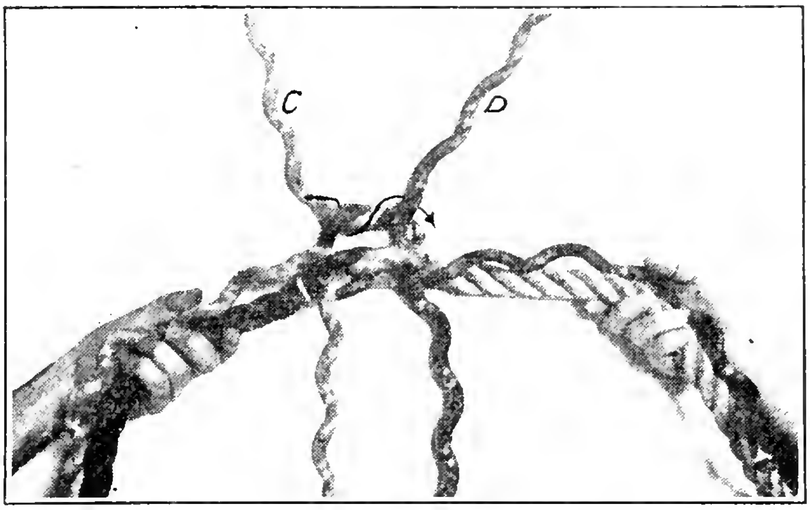

Fig. 64

4. Start twisting of the strands by tying each pair together with overhand knots, having the direction of twist in the knot the same as the direction of twist in the strands, as shown by the arrow in Figure 64.

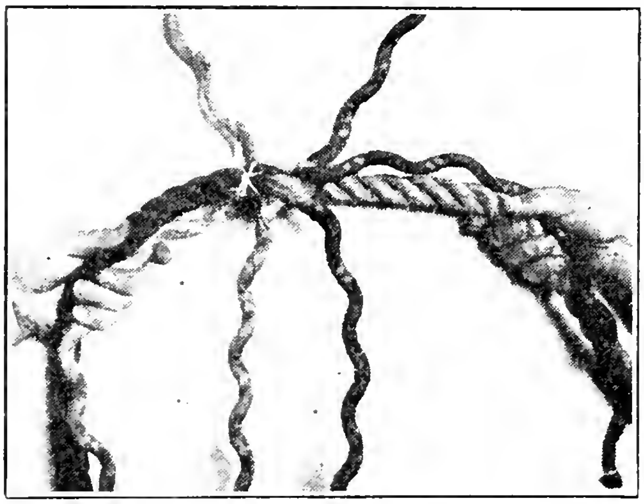

Fig. 65

5. Draw the three knots up tight by drawing each one up a little in turn, until they appear as shown in Figure 65.

6. Remove the string from the right-hand end of the knots and continue the twisting with the aid of a marline spike as shown in Figure 66, giving one strand two turns, one strand three turns, and one strand four turns about the strands they are tied around.

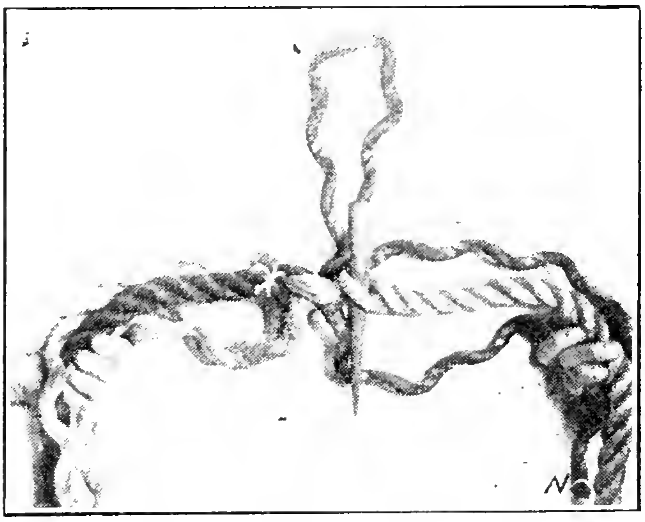

Fig. 66

A *marline spike* is a piece of wood of the shape shown in Figure 66 and is used to separate the strands in splicing rope. This one has a hole in the end in which the strand of rope may be placed with ease when the ends are whipped as shown at *N* in Figure 66 on the preceding page.

Be sure you continue the twisting in the same direction as it has been started in tying the knots. Keep the same pair of strands together all the time and twist the strand you are working with up tight every time it is put around the other, as this is the only way to get a firm, compact splice. Try to have the slope of the twist in each pair of strands the same as the slope of the twist in the yarns that make up the strand, as this will make a smoother splice. It is much better to work with three pairs at the same time than to complete the twisting of each pair separately.

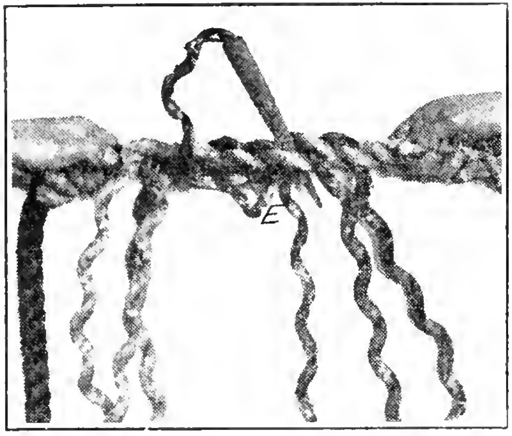

FIG. 67

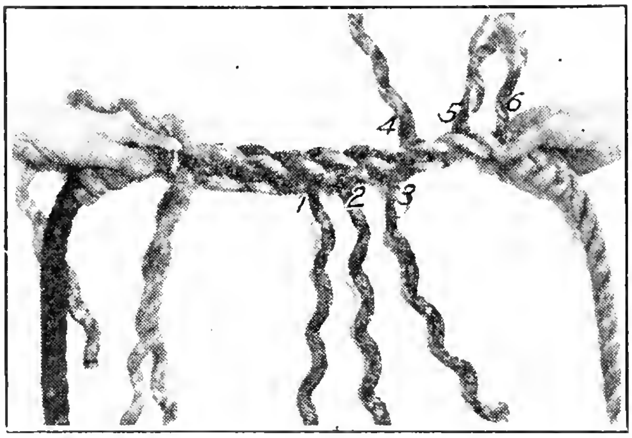

FIG. 68

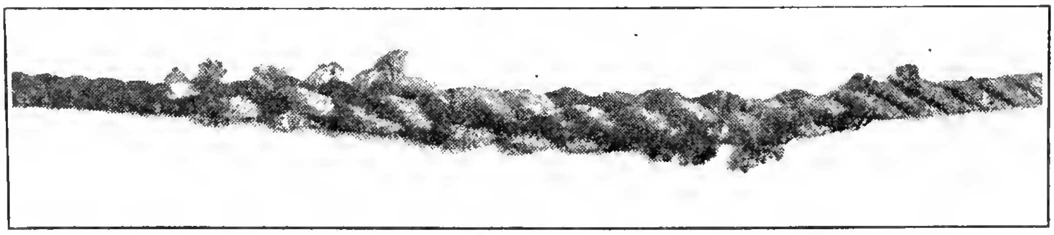

FIG. 69

7. Divide the strand that has been given two turns into two nearly equal parts as shown at *E* in Figure 67, and continue splicing with one part, giving it about three turns more.

8. Divide each of the other strands in the same way and give one part of each about three turns more. There should now be six half strands ending at different points along the splice as shown at 1, 2, 3, 4, 5, and 6 in Figure 68. The strands are divided to make the splice taper out gradually.

9. Remove the other string and finish that end of the splice in exactly the same way.

10. Finish the splice by cutting off the loose ends a short distance from the rope, as shown in Figure 69. If you cut the ends off close, they are likely to work loose. If your work has been done properly, you should be able to untwist the splice at any point, and it should show three separate strands, each one being twice the size of the original strands at the center of the splice.

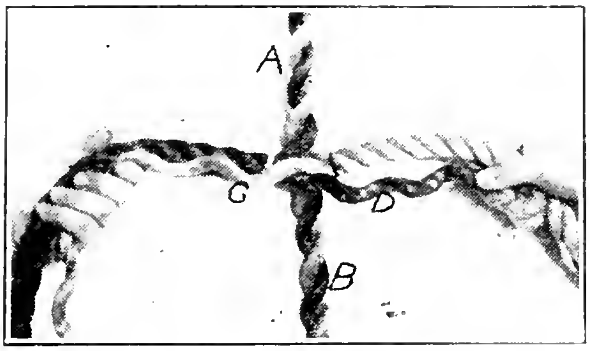

FIG. 70

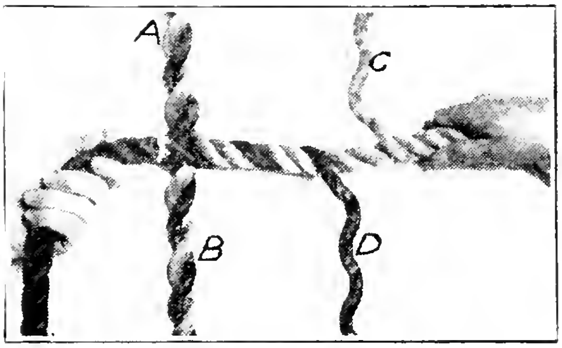

FIG. 71

Long splices. Long splices are used to fasten two pieces of rope together securely and are especially adapted to rope that must run over sheaves or pulleys in hoisting and transmission work, as the completed splices are the same size as the rope. In making one with three-strand rope observe the following directions:

1. Count off twenty turns (instead of seven and one-half as shown in Figure 60 for making the short splice) from the ends to be spliced and tie strings tightly around the ropes at the two points thus found.

2. Open and put the ends together in exactly the same way as shown in Figures 62 and 63, page 50.

3. Select the pairs as shown in Figure 63.
4. Twist two pairs together as shown at *A* and *B* in Figure 70.

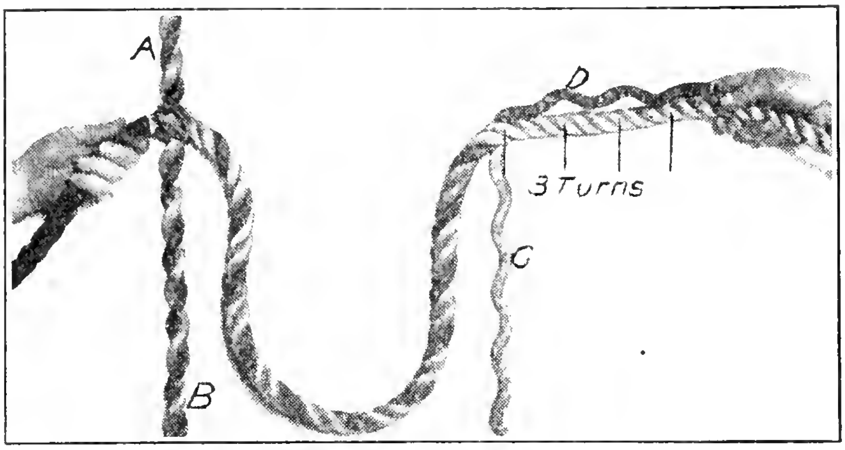

FIG. 72

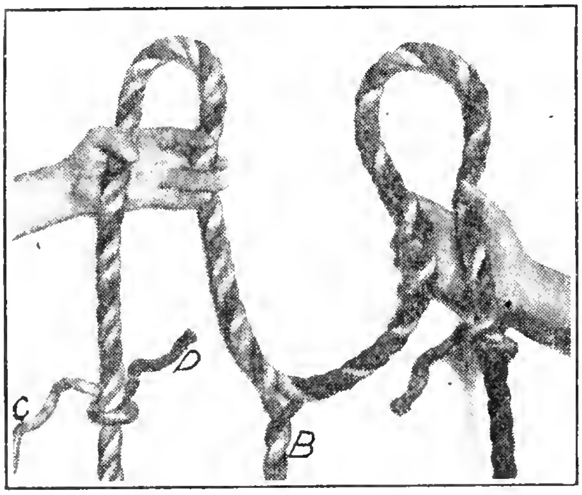

FIG. 73

5. Observing the cautions given below, remove the right-hand string and start the splicing by unlaying strand *C* and laying *D* in its place as shown in Figure 71. Continue this process until you have left only enough of strand *D* to reach a little more than four turns as shown in Figure 72. Then half hitch *D* around the rope so as to hold itself and *C* from untwisting, as shown in Figure 73.

C and *D* are on the left of Figure 73. The rope is usually turned, as it is easier to work toward the right hand; or else the workman gets on the opposite side of the rope.

Be sure that the ends of the ropes are forced closely together when you begin splicing. Be sure to keep the strand you are relaying, as *D* in Figure 71, twisted very tightly. As you unlay one strand, as *C* in Figure 71, relay the other in its place immediately; that is, keep them close together.

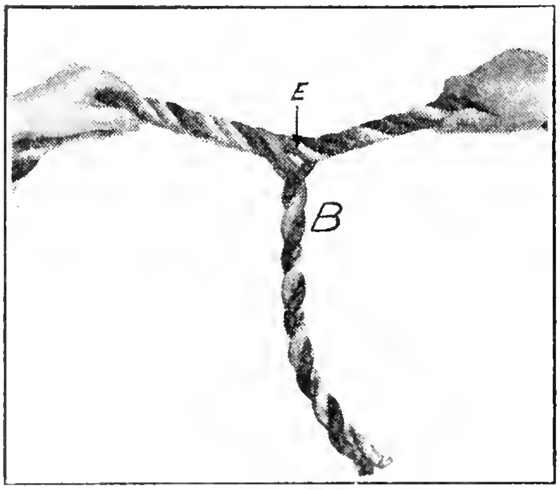

FIG. 74

6. Untwist the strands at *A*, in Figure 72, remove the other string, and then unlay one of the strands and lay the other in its place exactly as you did with *C* and *D*, but work in the opposite direction from the center of the splice as shown in Figure 73.

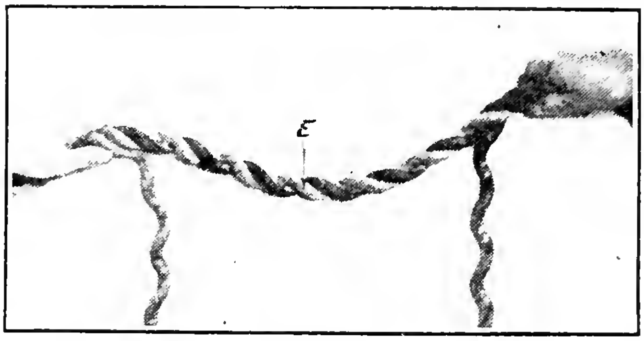

FIG. 75

7. Cut off the middle pair of strands, as shown at *B* in Figure 74, leaving enough of each one to reach at least four turns farther.

8. Unlay each strand of this pair three turns from the center point *E*, as shown in Figure 75.

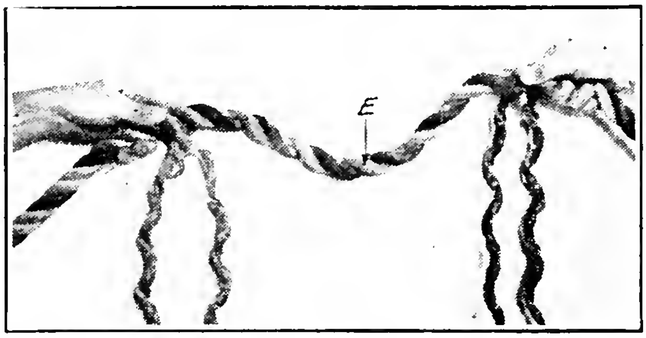

FIG. 76

9. Divide each strand into two equal or nearly equal parts, as shown in Figure 76.

10. Relay one part of each strand three turns again and tie an overhand knot, as shown in Figure 77. Tie this knot exactly as shown, which is just like the start of the short splice.

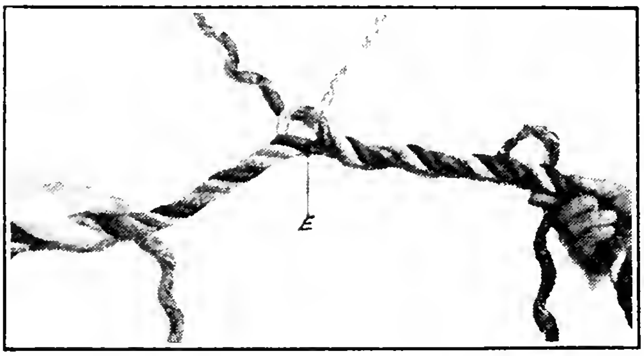

FIG. 77

11. Draw this knot up tight and then continue twisting these two parts of strands together as shown in Figure 78. The direction of twist and the method are the same as in making the short splice. Strand *F* should end at *K* and strand *G* should end at *H* as shown in Figure 79.

Be sure to keep the parts of strands twisted up tight. Do not twist either part of a strand around one of the other

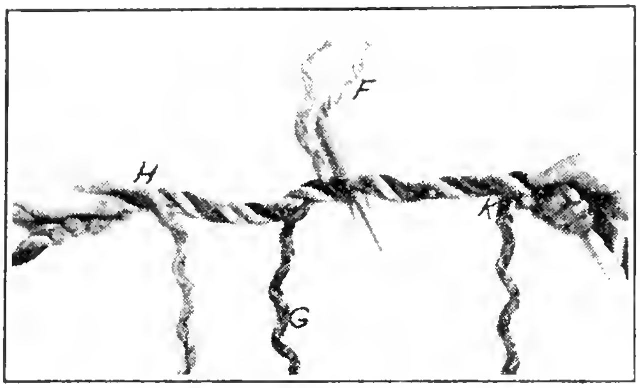

FIG. 78

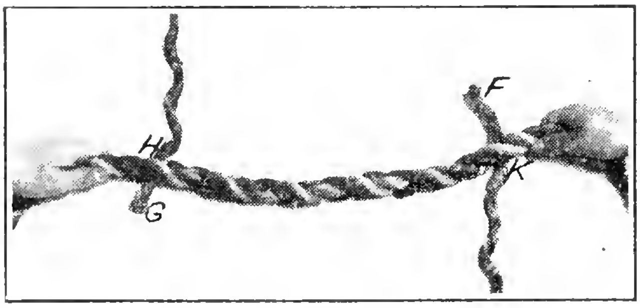

FIG. 79

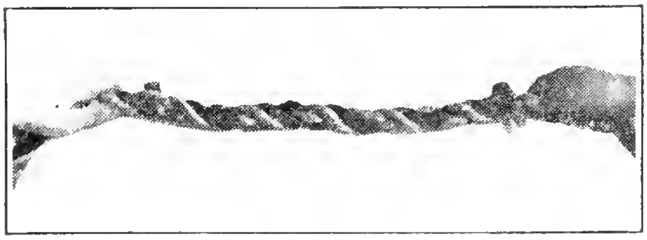

FIG. 80

whole strands. Have the slope of the twist the same as the slope of the twist in the other whole strands, for these two parts make a whole strand again.

12. Cut the ends of the parts of strands off a short distance from the rope as shown in Figure 80.

13. Finish one of the other pairs of strands by first loosening the hitch and cutting off the long strand, leaving it equal in length to the short one as shown in Figure 81. The remainder of the work of finishing this pair is exactly the same as for the center pair, starting with step No. 8.

14. Finish the third pair in a similar way and the

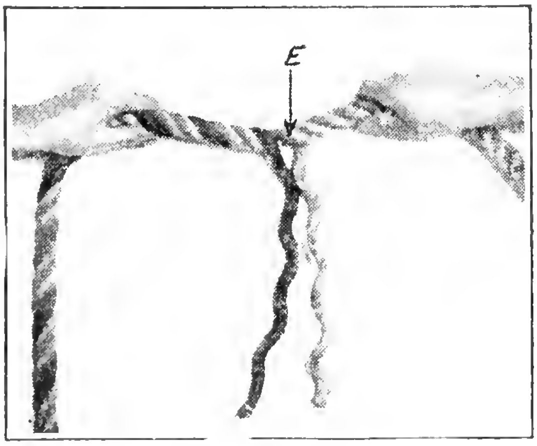

FIG. 81

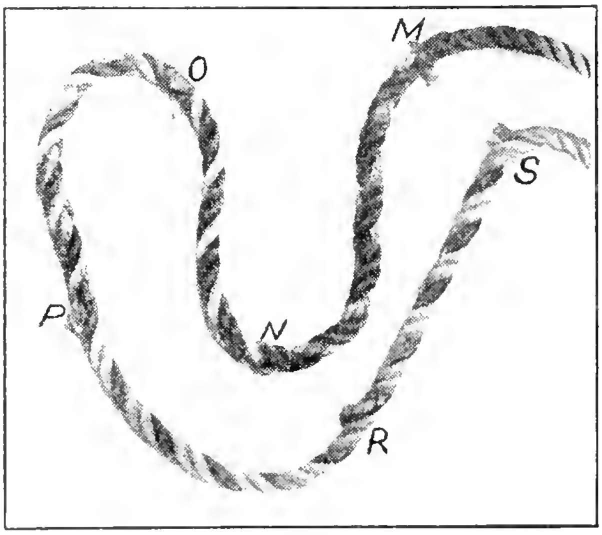

FIG. 82

completed splice should appear like Figure 82. There are two parts of strands ending at each of the points *M*, *N*, *O*, *P*, *R*, and *S*.

BLOCKS AND TACKLE

Block. A sheave or pulley or set of pulleys mounted within a shell or frame to which is fixed a hook, eye, or ring at one end for attaching it to a fixed or moving object and often a *becket*, consisting of an eye or some similar fastening, at the other end for attaching one end of the rope is called a *block*.

Tackle. A *tackle* is a mechanism of ropes, pulley-blocks, hooks, etc., for raising, lowering, and moving heavy objects. Some of the common names applied to a tackle consisting of two blocks and a rope are: fall and tackle, set of falls, set of blocks, and pair of blocks.

That ply of the rope of a tackle to which the power is applied is called the *fall-rope*.

The block from which the fall-rope passes is called the *fall-block*.

The block shown in Figure 83 is a double block with a becket.

The lower block in Figure 84 is a double block without a becket.

The fall-block in Figure 86 is a triple block without a becket.

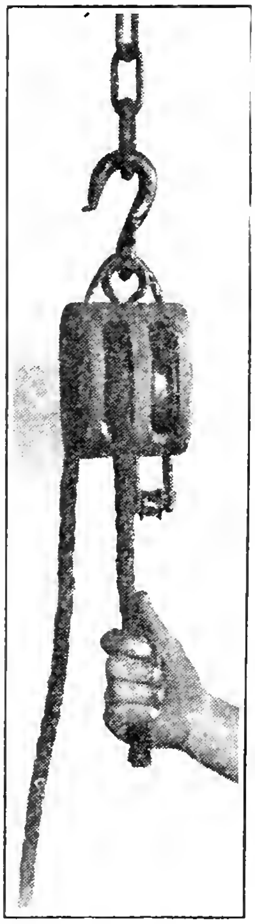

FIG. 83

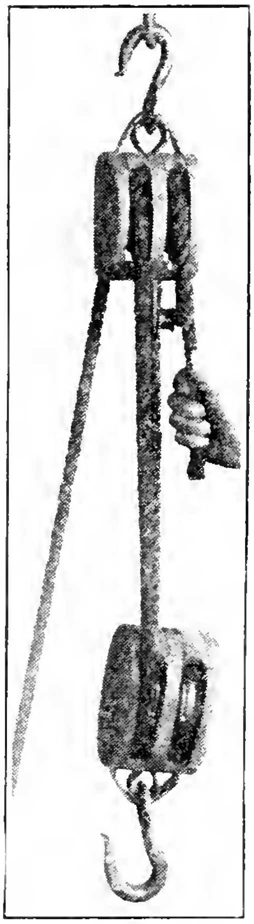

FIG. 84

The fall-block *B* in Figure 87 is a single block with a becket.

The lower block *A* in Figure 87 is a single block without a becket.

Reeving blocks. Reeving blocks is the process of passing the rope through the blocks in the proper way so as to get them ready for use. In any set of blocks one of them has a becket to which one end of the rope must be fastened. If both blocks have the same number of sheaves, the one having the becket is the fall-block. If one block has one sheave less than the other, the becket must be on the block with the smallest number of sheaves, but the other is the fall-block.

In reeving blocks by the directions which follow, the rope is passed through the blocks in the direction opposite to that in which it runs when the blocks are being used to lift or pull. This is to avoid the necessity of pulling all the rope through the blocks in order to get them reeved.

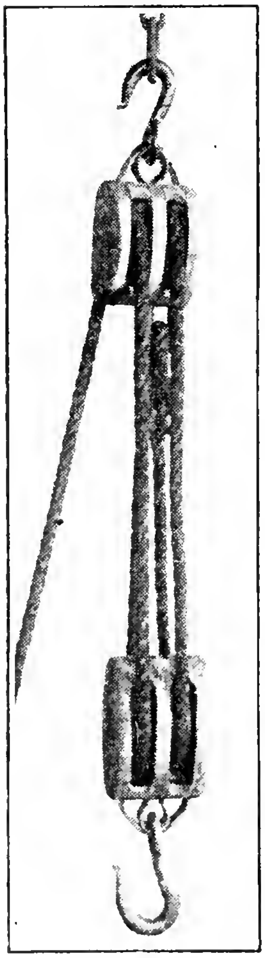

Fig. 85

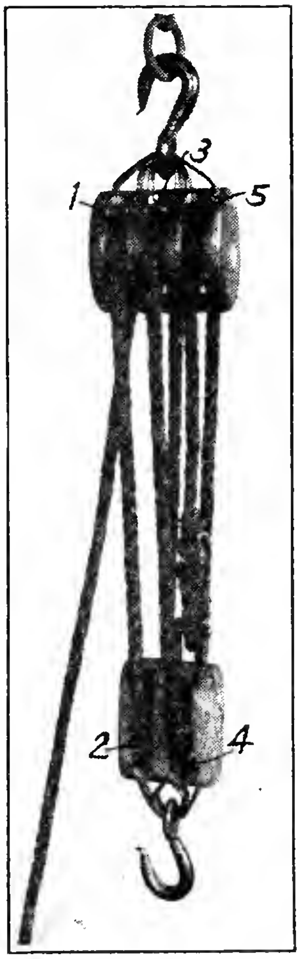

Fig. 86

A set of blocks in which both blocks have the same number of sheaves is reeved in the following way:

1. Start with the block having the becket, the fall-block, by passing the rope over the sheave which is farthest from the becket as shown in Figure 83. If the becket is in the middle, the rope may be passed over either outside sheave.

2. Pass the rope over the proper outside sheave in the other block and then over the next sheave in the block,

having the becket as shown in Figure 84, at the foot of page 57.

3. Now pass the rope back and forth from block to block, always passing the rope over the sheave next to the ones the rope has been passed over until all the sheaves are filled, and then fasten the end that you have been passing over the sheaves to the becket with a spliced eye, like the one shown in Figure 52. When completed the work should appear as shown in Figure 85.

A set of blocks in which the block having the becket has one sheave less than the other is reeved in the following way:

1. Start with the block without the becket, the fall-block, by passing the rope over one of the outside sheaves, as Number 1 in Figure 86.

2. Pass the end of the rope in the right direction over the sheave in the other block which is farthest from the becket, as Number 2 in Figure 86.

Start in the same way even if the block having the becket has only one sheave. If the becket is in the middle of the block, start with either outside sheave.

3. Now pass the rope back and forth from block to block, always passing the rope over the sheave next to the ones that the rope has been passed over until all the sheaves are filled, and then fasten the end that you have been passing over the sheaves to the becket with a spliced eye made as is the one shown in Figure 52. The completed work should appear as shown in Figure 86.

Lifting force of blocks. The load that can be lifted or moved with a set of blocks by application of a certain force to the fall-rope depends on (1) the number of plies of rope leading from the block that is fastened to the load; (2) the direction of pull when the fall-rope leads from the block fastened to the load; (3) the amount of force necessary to overcome the friction in the sheaves and the stiffness of the rope, and (4) the ultimate strength of the rope and parts of the blocks, for as soon as we strain any part to the breaking point, the blocks will give way.

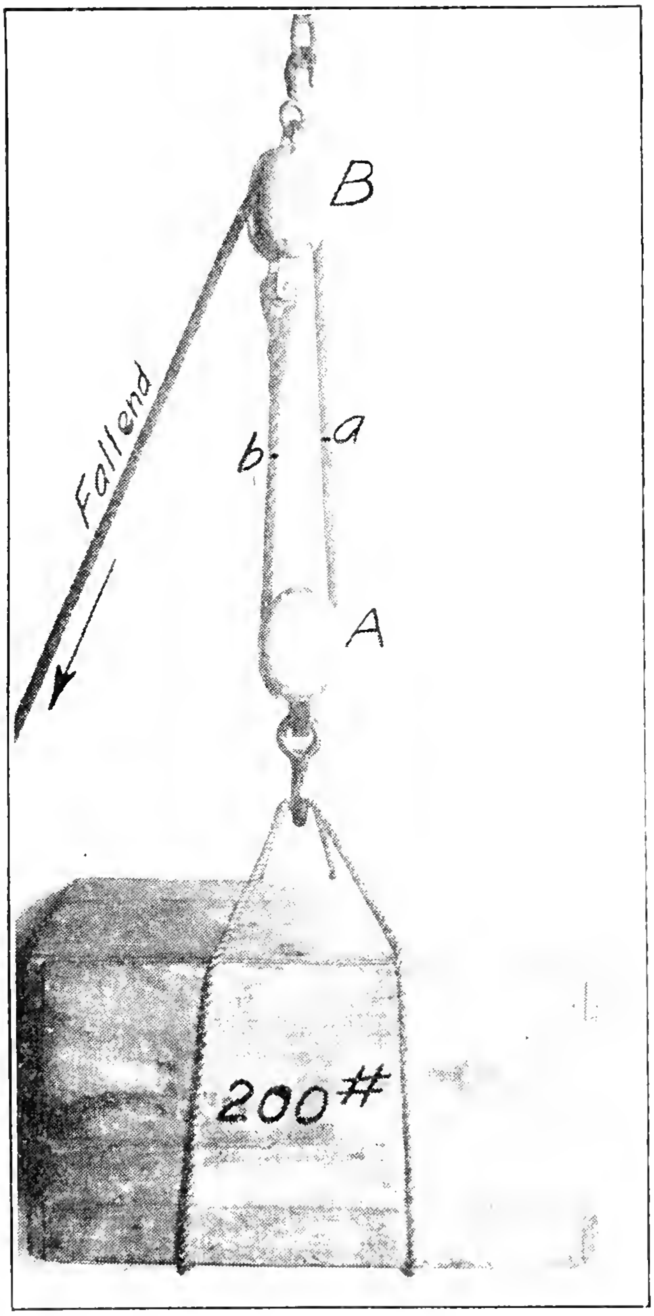

FIG. 87

Suppose that the two plies of rope leading from block *A* in Figure 87 are cut at the points *a* and *b*, and a spring scale tied between the ends of each ply. Now if a pull of 100 pounds is exerted on the fall-rope, each of the scales will show it is holding a force of approximately 100 pounds, the small error being due to friction and the stiffness of the rope. This would show that all parts of the rope are under the same strain or tension. Since each of the scales lifts on block *A* with a force which is nearly equal to 100 pounds, the block *A* will lift on a load with a force which is a little less than 200 pounds. We thus see that the block *A* lifts with a force which is nearly equal to the pull on the fall-rope times the number of plies leading from block *A*. If the pull on the fall-rope is 100 pounds and directly downward, parallel to the other plies, we then have three plies pulling down on block *B*, so that block *B* pulls down on its support with a force of approximately 300 pounds. It is thus seen that the pull exerted by the fall-block on its support is greater than the pull or lifting force exerted by the other block on the load, by an amount which is equal to the pull on the fall-rope.

By application of the same method of reasoning to Figure 85 a weight may be lifted which is nearly equal to four times the pull on the fall-rope, for there are four plies leading from the block which would be attached to the load. The fall-block will pull down on its support with a force which is nearly five times the pull on the fall-rope.

In a similar way by use of a set of blocks like those shown in Figure 86 a weight may be lifted which is approximately five times the pull on the fall-rope. The pull down by the fall-block on its support will be nearly six times the pull on the fall-rope.

Moving heavy objects. In the previous discussions regarding the lifting force of blocks it has been shown that the fall-block pulls down on its support with a force which is greater than that exerted by the other block on the object to be lifted. It is then advisable, if possible, when heavy objects such as buildings are to be moved, that the fall-block be fastened to the object to be moved. The pull on the fall-rope should also be directly toward the fixed block. In this way all of the pull exerted on the fall-block will be in the same direction and it will have a greater effect on the object to be moved. When the fall-block is not fastened to the object to be moved, the pull on the fall-rope may be in any direction, without changing the direction or amount of the pull exerted on the object to be moved.

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CHAPTER IV

MECHANICS OF MATERIALS

"Mechanics of materials" is the science which deals with changes occurring in the size and shape of bodies when they are subjected to external forces. The external forces are applied in various ways and produce different changes, known as *deformations*, which conform to definite laws. The forces are generally applied slowly, and the changes in size and shape take place accordingly.

STRESS

Definition. *Stress* is an internal force, set up within the material composing a body, which resists the tendency to change in size and shape due to the action of an external force. As long as the external forces are not so great as to cause any break in the material, the stresses are equal to the external forces causing them, and the two hold each other in equilibrium. Both sets of forces are measured in pounds per square inch.

Simple stresses. Simple stresses are as follows:

Tension. When a weight is hung on the end of a rod (Fig. 88) it produces a stress within the rod which is called *tension.* This stress tends to hold two adjoining planes within the body from being pulled apart. The total internal stress is equal to the total weight and is distributed uniformly over the whole cross section of the rod.

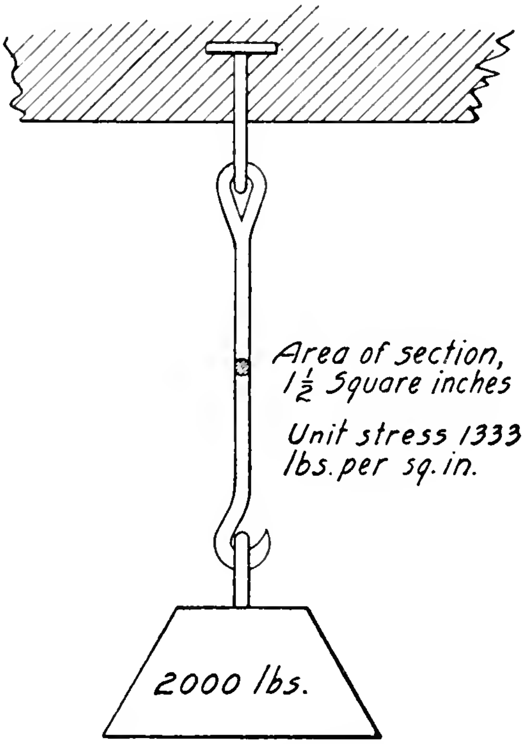


FIG. 88. *Tension*

On every unit of surface there is a certain stress, and this stress multiplied by the total number of units in the cross section is equal to the total force at the end of the rod. The amount of stress on each unit of surface is called the *unit* of stress and is commonly measured in pounds per square inch. If the rod has a cross-sectional area of 1½ square inches, the unit stress is 1,333 pounds per square inch. Figure 89 shows typical fractures caused by tension. The first is a brittle material, and the second is one of a more plastic nature which draws out and necks in before it breaks.

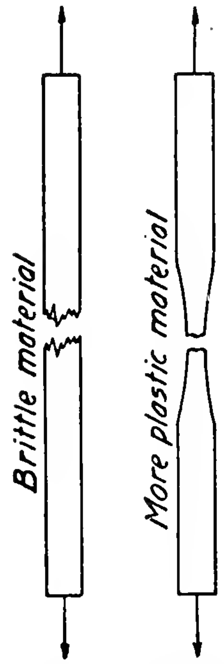


FIG. 89. *Change in materials caused by tension*

Compression. Figure 90 illustrates another kind of simple stress. This is called *compression.* As the figure shows, it is a stress which resists a tendency to crush the material. In this case, also, the stress is distributed uniformly over the whole cross section of the body and may be measured in pounds per square inch. Figure 91 shows a typical fracture, under compression, of a brittle material such as brick or stone, of a less brittle material such as wood, and of a material such as lead, which is so plastic that it will not actually rupture at all when subjected to compression, but will flow out.

Shear. Figure 92 illustrates a third kind of simple stress, called *shear.* It is a stress which resists a tendency to slip two adjoining planes within the body past each other. It derives its name from the fact that the forces producing it act in a manner similar to the blades of a pair of shears. As in the cases of tension and

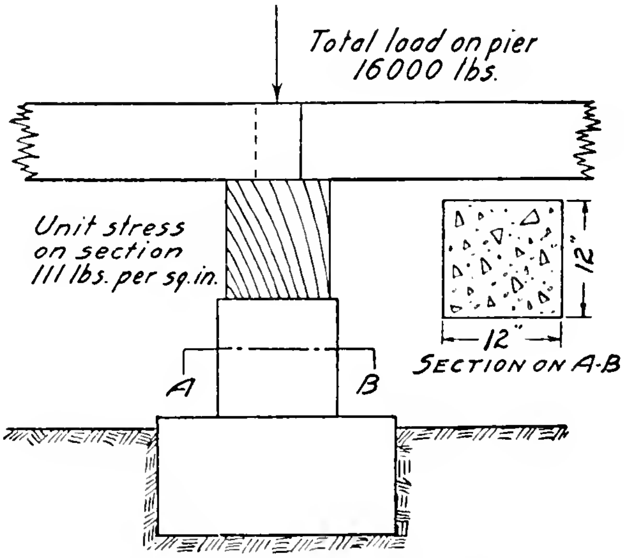


FIG. 90. *Compression*

compression, simple shear is distributed uniformly over the cross section and may be expressed in pounds per square inch. The fractures shown in the first two parts of Figure 91 are explained by the fact that the shearing stresses caused by the compressive forces become large enough to cause ruptures along surfaces at an angle with the axis of the body.

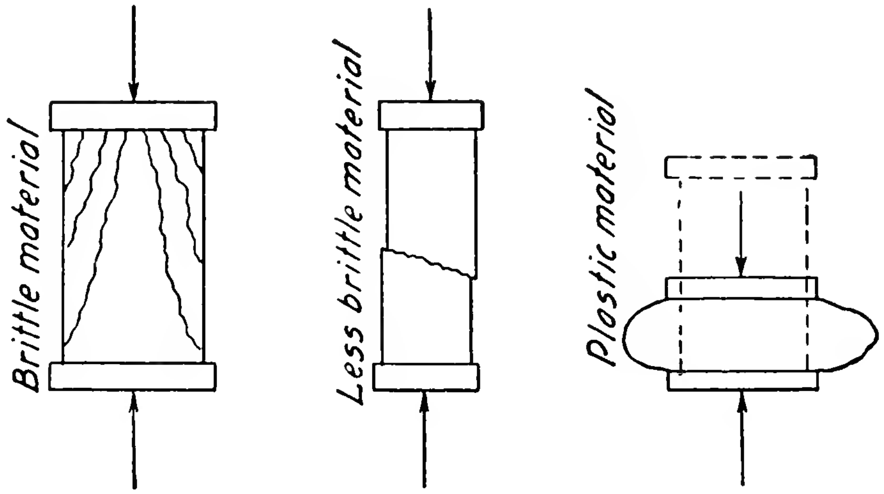


FIG. 91. *Change in materials caused by compression*

Complex stresses. As stresses are found in parts of structures and machines they seldom exist as simple stresses, but are found combined with each other in many different ways.

Flexure. Figure 93 shows a simple beam. The stresses set up in it due to its own weight and the weight of the load supported by it are a tension in the fibers near the lower side and a compression in the fibers near the upper side and shearing stresses in both vertical and horizontal planes. This combination is called *flexure.* Examination of a plank which has been broken when supported as above will show quite plainly that the fibers near

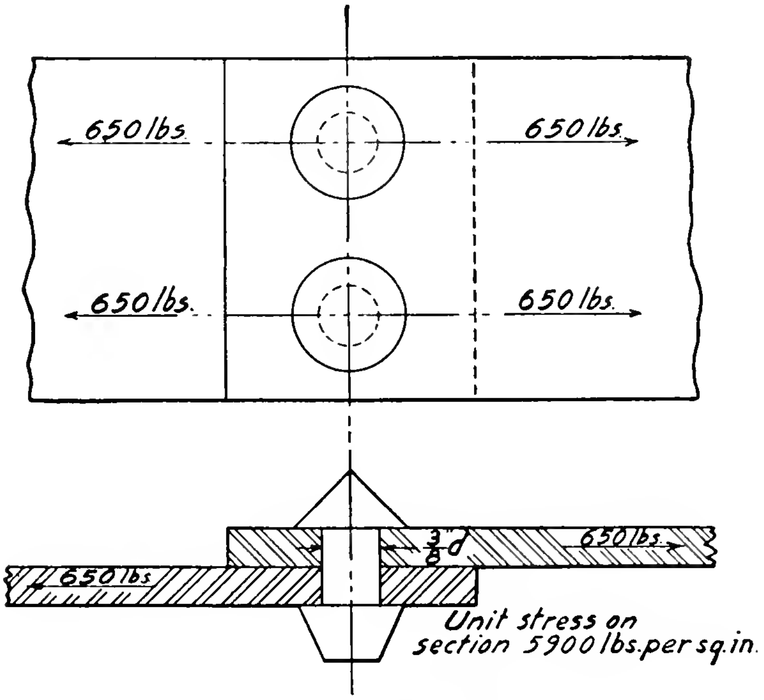


FIG. 92. *Shear*

the lower surface have been pulled apart and those near the upper surface have been crushed together. This is the usual way in which a simple beam breaks. In addition to the compression and tension there is a vertical and horizontal shear, as mentioned above. The fact that there is a horizontal shear is quite clearly illustrated by the example of a pile of planks placed in the position of a simple beam (Fig. 94). It will be seen that sliding of one surface on another has taken place. This same tendency to slide between horizontal surfaces is present in a solid beam, but is resisted by the strength of the material. For this reason the solid beam will not deflect as much as the pile of planks. The vertical shear is not quite so evident, but examination of Figure 93 will show that on any section of the beam, such as *AB*, the support below the beam pushes upward on one side and the load on the beam pushes down on the other, tending to move one part of the beam along an imaginary surface dividing it from the other part, thus producing vertical shearing stress.

Since the stress within the beam varies from compression at the top to tension at the bottom, there must be some surface between the top and bottom surfaces where the stress changes from tension to compression—where there is no stress at all. This surface is called the *neutral surface.*

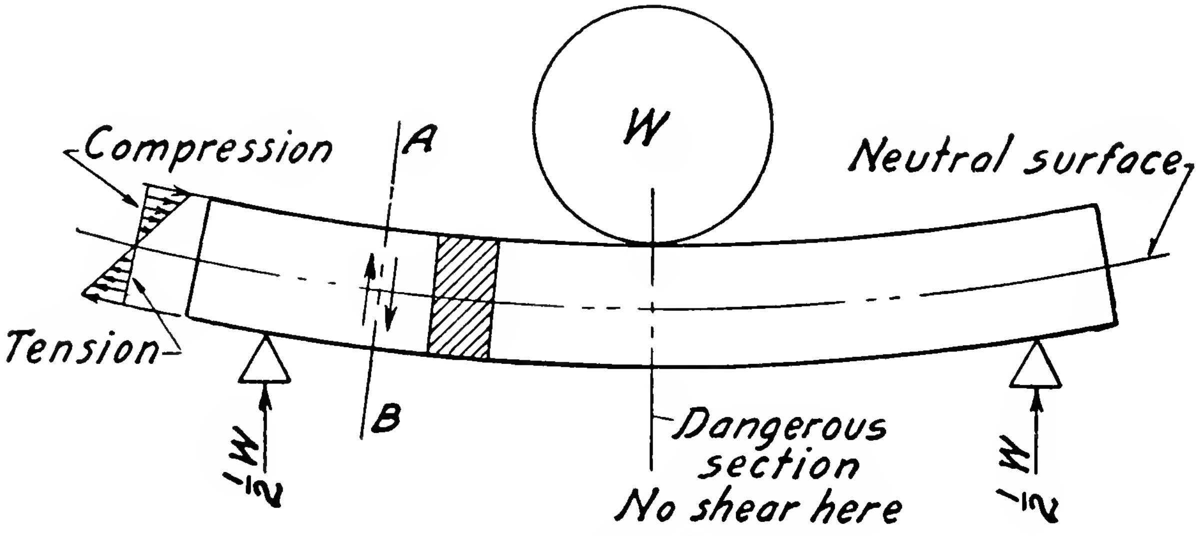


FIG. 93. *Flexure in a beam*

All fibers above it are subject to compression and all fibers below it to tension. In a beam having a rectangular cross section and made of the same material throughout, this neutral point is just halfway between the top and bottom. In beams of unsymmetrical sections or ones that do not have the same kind of material throughout, such as reinforced concrete, the neutral surface does not fall exactly halfway between the top and bottom, its position being determined by the shape of the beam and the properties of the materials. The degree of stress increases from zero at the neutral surface to a maximum compression at the top and a maximum tension at the bottom.

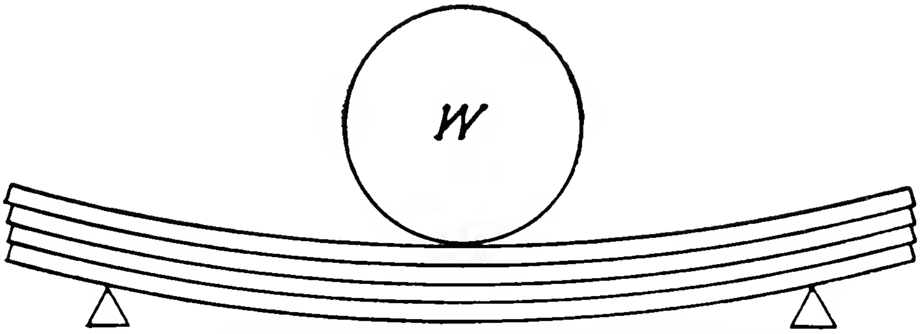


FIG. 94. *Showing the tendency to slide along the longitudinal elements of a flexed beam*

If the load on the beam is placed at the center or is evenly distributed both ways from the center, then the most dangerous section falls directly at the center of the beam. If the loading is other than this, then the dangerous section is at some other point, depending on the position of the load. It can be shown that, wherever this section is, there is no shearing stress at that point.

Torsion. Figure 95 shows a case of *torsion* or *twisting* such as occurs in shafting. The stresses which are present are shear on any transverse section, and tension on the fibers running spirally in one direction, compression on fibers running spirally in the other direction. Brittle materials fail in the tension fibers, fibrous materials split apart, and plastic materials shear off squarely under such conditions.

Combined stresses. Many combinations of stresses occur in structures and machines, such as flexure combined with torsion, flexure with compression, flexure with tension. In the designing of structures or machines due consideration must be given to all the stresses present, and enough material provided to supply sufficient strength.

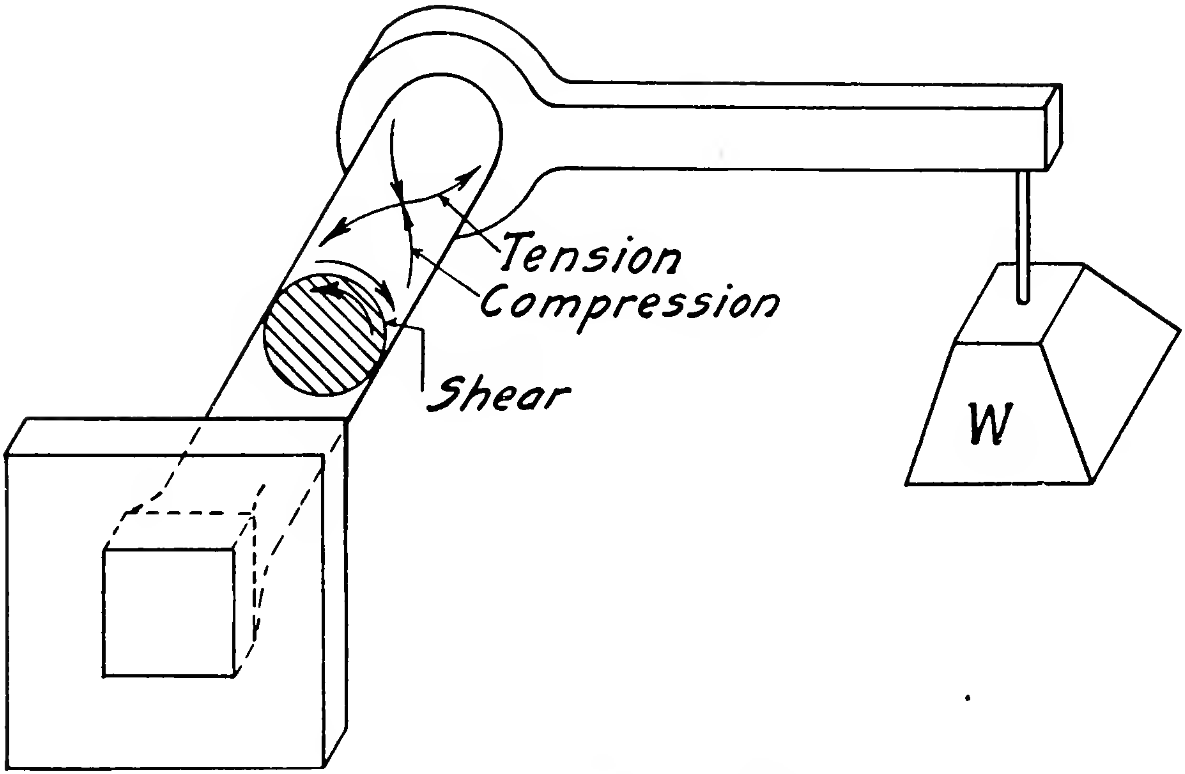


FIG. 95. *Torsion, or twisting*

Temperature stresses. All solid bodies expand when their temperature is increased and contract when their temperature is decreased. If they are so placed that this tendency to expand or contract is resisted by the parts to which they are attached, temperature stresses are set up within the bodies. A good example of this is the steel tire on a wagon wheel, which is heated and shrunk on and remains under tension when in service.

Deformation. External forces produce deformations in the bodies upon which they act. Tension produces elongation, compression produces a shortening, and shear produces a detrusion or slipping. The amount of deformation in each case is in proportion to the force producing it unless the force is large enough to strain the body beyond the so-called elastic limit of the material. This elastic limit varies with different materials. It is the largest unit stress which the material will stand and still return to its original state when the force causing the deformation is removed. The word "strain" is sometimes confused with "stress." Strain means the same as deformation. The expression "stress and strain" is synonymous with "stress and deformation."

When a body is stressed beyond its elastic limit, the amount of deformation produced by a given force is not in proportion to the magnitude of the force, and the body receives a permanent change of shape, the extent of which depends not only upon the magnitude of the force producing it, but also upon the length of time during which the force acts. For example, a tensile stress may become so large that the material will continue to stretch as long as the force is applied or until an actual break occurs.

Forces acting to produce tension or compression always produce shear along certain planes. This is illustrated in Figure 96. These shearing stresses are zero along the planes at right angles to or parallel with the longitudinal axis of the body, and are at a maximum on planes cutting the axis at 45°.

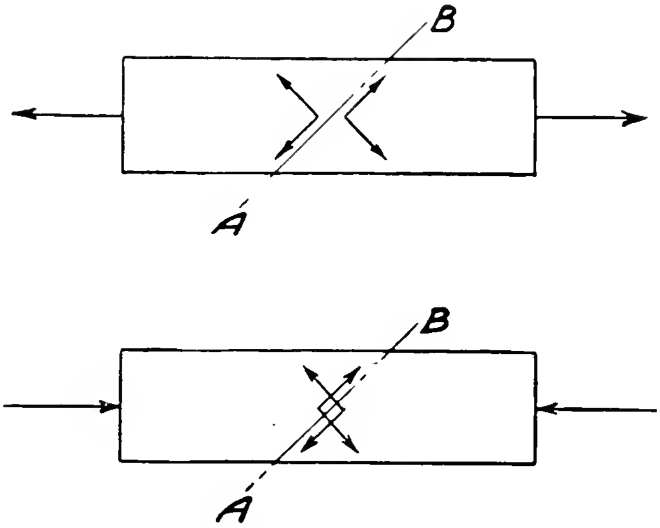
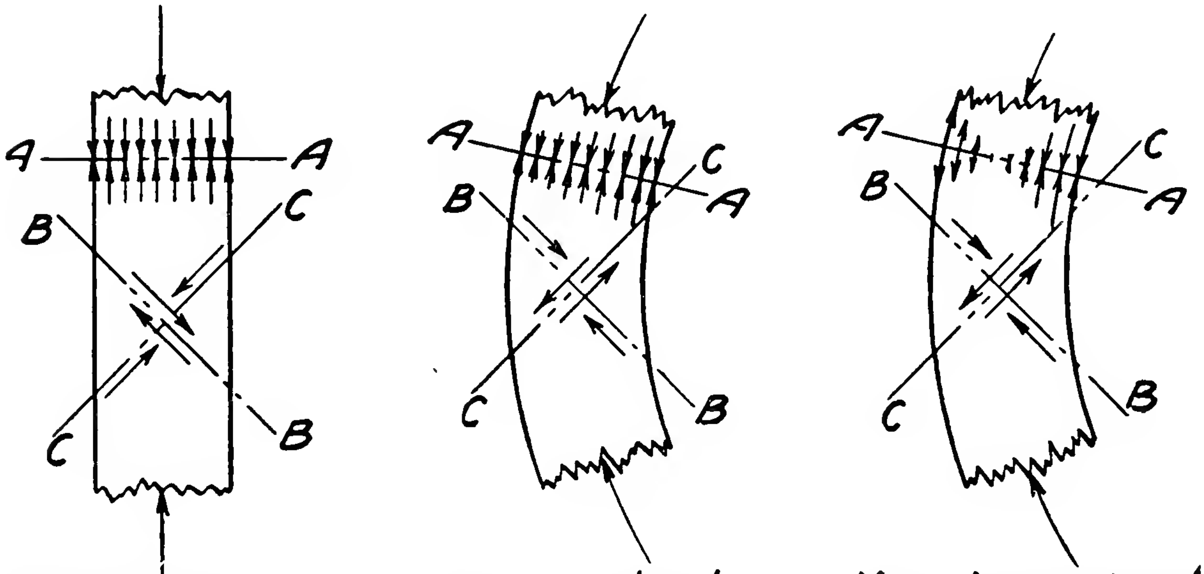
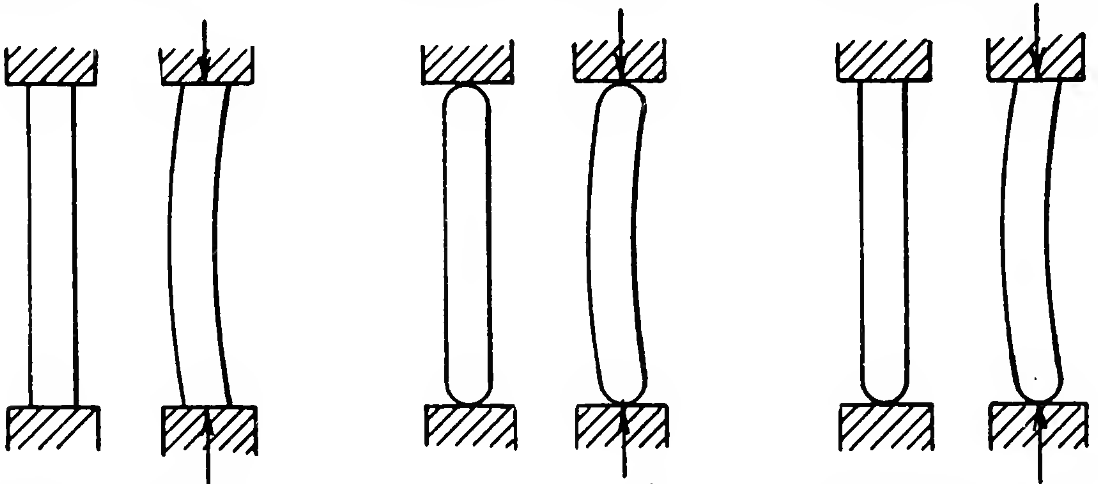


FIG. 96. *Direction of shear in a body which is subject to tension or compression*

Forces applied suddenly. The forces so far considered are assumed to have been applied slowly. It should be understood that forces, whether tensile, compressive, or shearing, produce far greater stresses if they are applied suddenly. A weight dropped from some considerable height upon a beam may cause it to break, when if it were brought on slowly the beam would carry it. Some materials, such as steel, become fatigued if forces are applied to them repeatedly. This fatigue causes a loss of strength and elasticity. An effect somewhat similar to fatigue is



Light load Heavier load Very heavy load



Square ends Round ends Combination of round and square

FIG. 97. *Action of columns supporting a load*

produced when forces act on a body so as to produce a repeated variation of stress, such as tension to compression and back again.

Columns. When the length of a body under compression is more than eight or ten times its smallest lateral dimension, the body has a tendency to bend or buckle. Such a body is called a *column*. Figure 97 represents the nature of the stresses in column sections. There are compression and shear present in all cases, no matter what the load may be;

and in the very heavy loads, in addition to the compressive stress which would be present in a shorter compression member, there is a tension on one side and additional compression on the other because the column has a tendency to bend. The shape or method of fastening the ends of the column has an influence on its power to resist this bending. The square-end columns are stronger than those with round ends. The diagrams show several common forms of columns.

Columns constructed of different materials generally fail in different ways: cast iron by crushing on one side; timber by crushing the fibers owing to direct compression or because of a tensile stress caused by bending; concrete columns by shearing off at an angle; and structural steel by buckling.

Factor of safety. In the designing of structures only a portion of the strength of material is used, a certain portion of the strength being allowed for poor materials, faulty construction, and unusual strains. This extra allowance of strength is known as the *factor of safety*. For example, a beam which according to tests would carry 24,000 pounds, if placed under a working load of 8,000 pounds would have a factor of safety of 3.

CHAPTER V

CLIMATOLOGY

The climatic conditions which have the most notable effect upon agricultural production and the limiting of certain crops to special areas are temperature and rainfall. These two factors, and in particular their variation from season to season and year to year, are the subject of much discussion.

Climatic cycles. In a general way both temperature and rainfall run in cycles. There are periods of cold and warm years and periods of wet and dry. Some of these are of longer duration than others, but no relation exists between their beginning and ending and the length of time throughout which they extend. However, there is a tendency gradually to increase and then decrease, several years elapsing between the extremes. Some authorities have estimated that it requires records covering thirty-five successive years to determine the averages for a given locality. It is doubtful whether this time is long enough to cover the greatest extremes. It would probably require observation for a century to get the maximum range of high and low temperature or the greatest and smallest rainfall on a specified area. The statements frequently heard to the effect that winters are growing warmer or the rainfall more plentiful have their foundation only in the cycles referred to. The records of the United States Weather Bureau indicate that there are no general climatological changes, and one may expect winters as cold, summers as hot, and seasons as wet or dry as have ever been experienced in the past.

Promoters frequently take advantage of a certain condition of season to develop agricultural interest in a locality affected. A few wet years in an arid region bring out the assertion that settling a country increases the moisture, that rainfall follows the plow, or that the breaking up of large areas of wild land has caused the winters to become less severe. Such statements are not based upon fact, as careful observations show conclusively that the unusual conditions are only a part of the local climatic cycle. Large areas of land have been settled upon the assumption that past conditions would not recur, lowlands have been broken up and farmed in dry seasons, arid lands have been cultivated in wet seasons, and crops adapted to certain temperatures have been introduced into colder climates because of the experience of a few years. Time brings disastrous results to the owners of such lands, for the cycle eventually changes. Repeated experience has shown that there is a tendency, during favorable seasons, rapidly to settle and place under cultivation large areas of land that have been considered unproductive. For a time the returns from such lands justify the expectations of the settlers, but sooner or later the pendulum swings toward the other extreme and much of the land becomes again valueless and is often abandoned.

In the selection of lands, where but limited capital is available every precaution should be taken to look up the weather records of that locality for the twenty or thirty years previous. The land should then be purchased on the assumption that the worst that has been experienced will be repeated. In this way provision can be made for tiding over the bad seasons. The records of the United States Weather Bureau are kept at many places and are available for determining, in a general way, the climatic conditions over a reasonable length of time. Advice should be sought from residents of long standing rather than from those who are interested only in land promotion and have little knowledge outside of the current years. Attention to these matters would frequently save the settler much hardship and loss of savings. Investment in lands where there are indications of some adverse seasons should always be protected by a bank account of sufficient size to provide living expenses through such a period. Some cases are open to development which will tend to mitigate the unfavorable years, but it should be clearly understood that the settling of a country or any work that may be done on the surface has no effect on the climate and that climatic conditions which have existed will return.

Temperature. Temperature cycles have been mentioned above. One period of years will not only have an average temperature considerably lower, but the maximum will be below that of some other period. Consequently temperature may be said to be constant only within certain limits. Ranges of hills or mountains may cause some variation, owing to the deflection of the prevailing winds; large bodies of water also have considerable effect because of the fact that winds blowing over the surface of the water are affected by its temperature. This causes the belt of land along the shore to remain cold longer in the spring, and to keep warm longer in the fall, than lands a few miles away. This is frequently favorable to fruit growing in climates where the fruits are injured by the late frosts of spring. The cold wind from the water holds the blossoms back and prevents early budding, so that when there is sufficient heat to develop the buds all danger of a killing frost has passed. In the fall of the year the winds are warmed by the water and prevent early frosts. An area properly located with relation to a large lake may therefore have a more favorable temperature for fruit growing than an unprotected area many miles south. However, both ranges of mountains and bodies of water are natural factors in the modification of climate and are not to be considered in the same class as that suppositional agent, cultivation.

To determine the temperature of an area with regard to its suitability for the cultivation of crops, it is necessary to study the weather reports for a number of years. The average for a year or any given month is not sufficient. A crop may be seriously injured by a low temperature for only one night, without any regard to the average. Consequently the whole record should be examined carefully so that one may be assured that this has not been sufficiently low during any twenty-four hours to do permanent damage. The time of the last killing frost in the spring and the first killing frost in the fall indicates the length of the growing season for plants susceptible to slight cold or frosts. The average temperature of one of the early spring months and one of the late fall months may be such as to indicate that both of these months are suitable to plant growth, yet one low temperature might occur near the end of the spring month or near the beginning of the fall month that would eliminate both from the growing season. The temperature records that interest the agriculturist are the maximum and the minimum that occur in any twenty-four-hour period of the month, and the dates of the last killing frost in the spring and the first in the fall.

TABLE SHOWING TEMPERATURE DATA FOR A TEN-YEAR PERIOD IN DULUTH, ST. LOUIS COUNTY, MINNESOTA, 1900–1910*

YEAR	LENGTH OF RECORD YEARS	DEPTH OF SNOWFALL	ANNUAL MEAN	HIGHEST		LOWEST		LAST KILLING FROST	FIRST KILLING FROST
				Degrees	Date	Degrees	Date		
1900	30	31.9	41.2	93	July 30	−22	Jan. 31	May 4	Nov. 6
1901	31	42.0	40.0	98	14	−26	Dec. 14	Apr. 19	Oct. 16
1902	32	45.8	40.6	86	23	−22	Jan. 27	30	14
1903	33	52.9	39.1	92	7	−24	Feb. 17	16	Sept. 27
1904	34	50.0	36.0	85	Aug. 14	−37	Jan. 24	May 16	Oct. 6
1905	35	30.5	38.2	91	29	−29	Feb. 13	9	11
1906	36	60.0	39.0	89	Sept. 8	−22	5	7	6
1907	37	46.1	36.4	88	June 16	−28	Jan. 28	8	Sept. 25
1908	38	44.7	39.8	92	July 10	−29	29	4	28
1909	39	52.3	38.0	87	June 29	−34	6	10	Oct. 12

*Compiled from the records of the United States Weather Bureau.

Rainfall. Cycles of rainfall are similar to those of temperature, although there is no apparent relation between the two. A series of wet years will be followed by dry ones, the extremes being greater in one period than in another. Areas of land that in the wet period are considered swampy, or are full of lakes, become in the dry season sufficiently dry to be tillable and very productive. The beds of lakes are frequently plowed up and two or three good crops raised before the fields again become navigable lakes. Rainfall data are usually collected along with temperature data, and information is to be had in the publications of the Weather Bureau.

As with temperature, the amount of rainfall that affects farm production in a humid country is not dependent upon the average of a given month or year, but is determined by the amount of rainfall in twenty-four hours and the number of days in succession that the rain falls. An inch rainfall in twenty-four hours in a dry season may be beneficial, but an inch five days in succession might be destructive. On the other hand, an inch rainfall in five days would have hardly any bearing on crop production, but an inch coming at the end of several rainy days might be disastrous. Losses during wet seasons usually occur as a result of a series of heavy rains, coming close together, such that the land surface is not able to dispose of one rain before another comes. This fact explains the heavy losses sometimes occurring because of undue moisture in a year during which the average rainfall is at or below normal. Comparison of one region with another as to rainfall for agricultural production should be based on the daily rain and the number of successive days during which there is a probability of rain falling.

Disposal of rainfall. In the disposal of rainfall there are five factors: absorption, percolation, evaporation, plant growth, and run-off. Absorption is limited to the quantity of water that can be held by the soil grains; percolation to the quantity that can flow downward between the soil grains; evaporation by the conditions of wind and temperature; water used by plant growth by the growing condition of the plant; and run-off depends on the quantity

Table Showing Total Rainfall, Number of Days of Rainfall, Maximum Rainfall in Twenty-four Hours, at Power, Richland County, North Dakota, for Each Month of 1901 to 1904 Inclusive*

Month	1901			1902			1903			1904		
	Total Rainfall	Number Days of Rainfall	Maximum Rainfall in 24 Hours	Total Rainfall	Number Days of Rainfall	Maximum Rainfall in 24 Hours	Total Rainfall	Number Days of Rainfall	Maximum Rainfall in 24 Hours	Total Rainfall	Number Days of Rainfall	Maxi mum Rainfall in 24 Hours
	Inches		Inches	Inches		Inches	Inches		Inches	Inches		Inches
January	0.32	5	0.10	0.35	4	0.15	0.70	4	0.50	0.32	5	0.15
February	.20	1	.20	.66	5	.40	.92	5	.60	.85	6	.25
March	1.20	7	.47	1.78	5	.70	.40	5	.10	.82	5	.50
April	1.70	5	.84	2.17	4	1.41	1.34	6	.52	2.82	6	1.27
May	.17	5	.07	3.86	10	.88	3.23	3	1.71	1.01	5	.37
June	5.78	13	1.44	2.66	10	.75	.74	8	.16	7.59	11	1.90
July	8.14	6	6.36	1.73	6	1.10	2.82	7	.87	3.22	8	.98
August	1.33	7	.35	3.56	8	1.05	4.29	7	1.10	.71	6	.22
September	3.01	5	1.82	.65	4	.30	2.76	7	1.26	3.21	7	1.26
October	3.24	5	2.17	4.81	5	2.25	.97	5	.46	1.62	4	.74
November	.20	1	.20	.25	1	.25	.10	1	.10	.02	1	.02
December	.82	4	.60	.40	2	.30	.10	2	.05	.75	5	.30
Total	26.11	....	....	22.88	....	....	18.37	....	....	22.94	....	....

*Compiled from the records of the United States Weather Bureau, after John T. Stewart, *Bulletin 189*, O. E. S., United States Department of Agriculture.

(Note the total rainfall for 1901, 26.11 inches; for 1903, 18.37 inches. In July, 1901, one-third of the yearly rainfall fell, nearly one-fourth of the yearly rain coming on one day.)

of water that falls in a given time and on the quantity disposed of by the other four agencies in the same length of time.

Absorption. The soil takes up and holds a certain quantity of water between the grains. The longer the period that has elapsed since the last rain, the greater the quantity of water that will be absorbed.

Percolation. Some soils are of an open, porous nature and permit the water to percolate down to a considerable depth. In this way water may work its way in underground channels and finally find an outlet to the surface as springs. When the underlying stratum is of an open nature, the flow of water is facilitated, and when this stratum is overlaid by a porous covering, it may be possible for practically all the rainfall to be disposed of by percolation. Damage to crops will not occur from excessive rains in such a locality. However, under ordinary conditions there is a limit to the amount of rainfall which can be disposed of in this way.

Evaporation. Certain conditions of air and temperature tend to evaporate water on the surface and remove it as vapor in the air. Great quantities of moisture are at times removed in this way. Evaporation tables indicate that the annual quantity of water drawn back into the air from a body of water by this agency is frequently as large as, if not larger than, the rainfall. Hasty conclusion might lead to the error that evaporation is sufficient to prevent damage to growing crops from excessive moisture. If the evaporation and rainfall are uniformly distributed throughout the year, evaporation will remove the surplus rain; but excessive moisture, when conditions are right, can permanently injure a crop in twenty-four hours. Conditions may be such that at the time of the falling of the rain evaporation is practically stopped for a period of twenty-four hours. High winds and warm temperature are conducive to rapid evaporation, and when a rainstorm is followed by warm weather and strong winds, evaporation is very rapid. Frequently the records will indicate a heavy rainfall and high evaporation in the same twenty-four hours. At other times, however, the rainstorm is followed by a low temperature without any wind, and as a result the evaporation is very light. Where the surface is covered with a thick, growing crop which prevents the free circulation of air, evaporation may be prevented almost entirely, and several days may pass without the removal of water by this method.

TABLE SHOWING THE MONTHLY RAINFALL AND EVAPORATION FROM WATER SURFACES THROUGH THE GROWING MONTHS AT FARGO, NORTH DAKOTA, IN THE YEARS 1902–1905*

(Note that the monthly evaporation is practically double the rainfall.)

	May	June	July	August	September
	Inches	Inches	Inches	Inches	Inches
Average monthly evaporation	5.390	6.330	8.240	7.450	3.430
Average monthly rainfall	3.610	3.120	3.320	3.750	3.290
Excess of average monthly evaporation over rainfall	1.780	3.210	4.920	3.700	.140
Average daily evaporation	.174	.211	.266	.240	.114
Average daily rainfall	.116	.104	.107	.120	.110
Excess of average daily evaporation over rainfall	.058	.107	.159	.120	.004

*After John T. Stewart, *Bulletin 189*, O. E. S., United States Department of Agriculture.

During August, 1905, in the valley of the Red River of the North, a heavy rain occurred on Monday, followed by several lighter rains and another heavy rain on Thursday. The wheat crop was ripening and was ready to cut. As the soil of that region is very heavy and permits only a limited amount of absorption and percolation and the surface is comparatively level and at that time had few natural or artificial water channels, evaporation was the only agency that could remove the rainfall. Where the surface of the land was exposed to the sun and wind, evaporation took place quickly, but in the wet fields the rank growth of the grain effectively stopped evaporation and the ground was so soft that the binders would not operate, and a large part of the wheat crop was lost. It was found that in the fields where the binder had started before the rain one round could be cut in the morning because the surface from which the grain had been removed was sufficiently dry to hold up the binder, but the machine could not run on land from which the grain had just been cut. Twenty-four hours' time was required to dry the soil so as to hold up the binder. This illustrates the effect of evaporation in drying the soil as well as the effect of vegetation on evaporation. While evaporation is one of the drying agencies and very effective under certain conditions, it is uncertain and cannot be relied upon to remove moisture that is interfering with crop production.

Plant growth. The growth of plants requires a large quantity of water. Water is taken from the soil by the plant roots during the growing period and used in the structural system of the plant or evaporated from the surface of the leaves and the stems into the air.

Run-off. All rainfall not disposed of by absorption, percolation, evaporation, and plant growth is known as *run-off* and is the water that collects on the surface and flows over the surface into ditches and streams. On frozen or hard ground which tends to limit absorption and percolation, or where evaporation is limited by checking of the circulation of the air, or the quantity of water used in plant growth is limited because the rain comes at a season when plants are not growing, there is a tendency for the run-off to increase. A large run-off may be expected in the spring when the ground is frozen and the temperature is cold, and a small run-off in the middle of the summer when plant growth is the greatest, evaporation is at a maximum, and the ground is dry.

Injury to the growing crops from excessive moisture is due to the fact that they are drowned out by the run-off collecting and standing in depressions and on the low ground, and to the water-logging of the soil or the filling of the space between the soil grains which thereby prevents the circulation of air. Both flooding and water-logging are the results of one heavy rain or several rains coming in rapid succession. In looking at the data relating to the effect of excessive moisture on crop production it is necessary to determine the season of the year in which the greater part of the rain falls, the quantity of water falling in any twenty-four hours, and the rapidity with which one rain follows another. A rainy period before the crops are planted in the spring ordinarily causes no damage. The same amount of rain in June or July might mean a crop failure. Comparisons of the monthly rainfall or annual rainfall of an area in one state with that of another are made for the purpose of giving information about the drainage conditions or drainage channels. Such comparisons have no value unless the individual rainfalls are taken into consideration. The run-off to be disposed of in the growing season in the Red River Valley of the North is practically the same as that in southern Illinois, although the average annual rainfall in southern Illinois is one-half greater than in the Red River Valley. In Illinois the rainfall is distributed throughout the twelve months of the year, while in the Red River Valley there is a tendency for it to be limited to the spring and summer months.

Winds and sunshine. When winds are excessive they make a region disagreeable and cause inconvenience during the winter months by drifting the snow. In an arid country they may be the cause of rapid evaporation, which is detrimental where the water supply is short. In prairie regions the effect of the wind around buildings can be alleviated to a certain extent by trees planted on the two sides from which the prevailing winds blow. Sunshine has a bearing on plant growth, but ordinarily where the conditions of temperature and moisture are right the sunshine will be satisfactory. Wind and sunshine records are usually reported by the United States Weather Bureau and may be taken into consideration in determining the desirability of a certain locality as a suitable place for a farm home.

SUMMARY

Climatic conditions have a bearing on agricultural production.

Wet and dry, warm and cold seasons have a tendency to come in cycles.

Climatic conditions are not changing, and conditions in the future may be expected to be as mild or as severe as they have been in the past.

Agricultural production is more dependent upon the minimum and maximum conditions for twenty-four hours than on the monthly or yearly averages.

Climatological records are kept by the United States Weather Bureau and are usually to be found in any public library.

CHAPTER VI

LAND SURVEYS

Some knowledge of past and present methods of land survey is indispensable to the agriculturist, who must many times come in contact with questions of land boundary and description. Land boundaries are necessary to designate the limits of governmental jurisdiction and individual ownership. In the description of such tracts of land it is essential that the boundaries be described in such manner that the size and area may be mentally pictured and the corners so marked that the lines can be located on the ground. The work of marking these boundaries and recording the descriptive data is *land surveying.*

The following abbreviations and definitions have become standardized by use in the United States Land Office and are used in land literature:

N	North	Long	Longitude
S	South	Chs	Chains
E	East	Lks	Links
W	West	Sec	Section
T	Township	Cor	Corner
R	Range	W.C.	Witness corner
P.M.	Principal meridian	W.P.	Witness point
Frac'l	Fractional	S.C.	Standard corner
Temp.	Temporary	¼ Sec. Cor.	Quarter-section corner
Bdy	Boundary		
Decl.	Declination	M.C.	Meander corner
Lat.	Latitude	C.C.	Closing corner

Random line: A trial line run to determine the position of the true line

True line: The correct line run between two corners

Township exteriors: The lines bounding a township

Subdividing: Dividing a township into sections

Tally pin: A steel pin 12 to 14 inches long, used for marking the end of a chain length in land surveys. Eleven pins form a set.

Tally: Ten units of measurement. In land surveys ten lengths of the surveyor's chain, equivalent to 660 feet. A complete set of pins is required to mark a tally, the pins being changed from the rear to the front chainman at the end of each tally.

Land surveys are divided into two classes: (1) original surveys which establish the lines, boundaries, and monuments in unsurveyed territory; (2) resurveys, made for the purpose of relocating the lines, boundaries, and monuments which have been established by a previous survey.

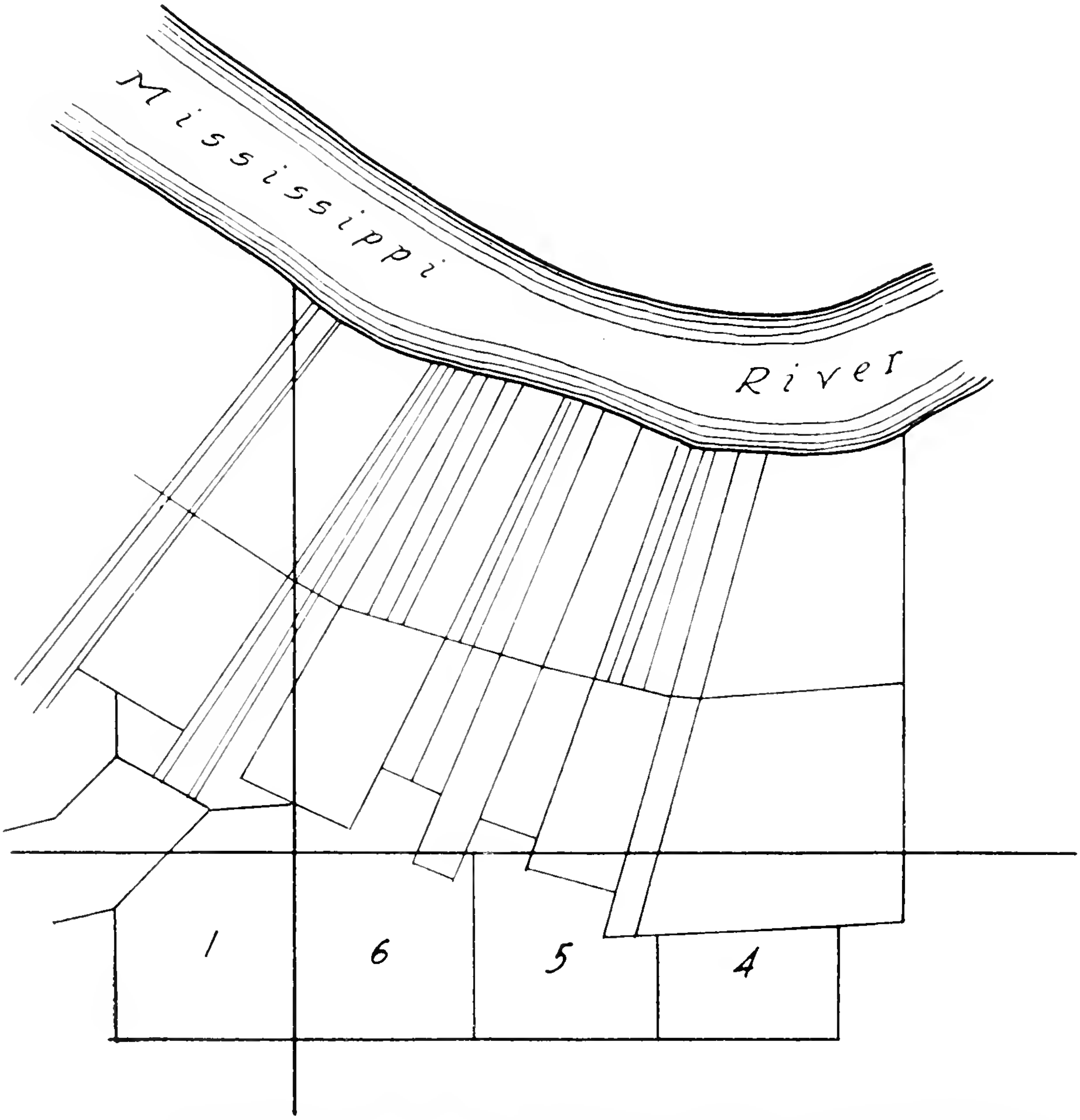


FIG. 98. *French claims laid out by metes and bounds to give each landowner river frontage. The numbered squares are United States sections.*

ORIGINAL SURVEYS

Metes and bounds. Metes-and-bounds surveys locate lands by surveying and describing the boundary of each tract independent of any other area. They were used in the original thirteen colonies, in Tennessee and Kentucky before 1785, and on lands acquired from France and Spain previous to their cession to the United States. The objection to this system is that the lands are in irregular tracts, not located with reference to any fixed monument, and from the written description several tracts cannot be definitely platted or located with relation to one another. Since 1785 the metes-and-bounds system (Fig. 98) has been used only to a limited extent for original surveys.

Rectangular system. The rectangular system is the method that has been used by the United States government in surveying all agricultural lands since 1785. This system is frequently spoken of as the United States land survey system or the General Land Office system of public surveys.

36	30	24	18	12	6
35	29	23	17	11	5
34	28	22	16	10	4
33	27	21	15	9	3
32	26	20	14	8	2
31	25	19	13	7	1

FIG. 99. *Method of numbering sections from the year 1785 to 1796*

History. The rectangular system was devised by a committee of Congress of which Thomas Jefferson was chairman. On May 20, 1785, Congress adopted the recommendation of this committee that lands be laid out in townships 6 miles square, containing 36 sections each a mile square. The law of 1785 provided only for the surveying of the township lines, leaving the section lines to be surveyed by private parties. The only lands surveyed under this law were in southwestern

Ohio. The sections were numbered in the order indicated in Figure 99.

In 1796 the law was changed to provide that lines should be run every 2 miles in a a township, and the method of numbering sections was changed to that used at the present time (Fig. 100). In 1800 the law was revised to provide for the survey of each section line, and in 1805 provision was made for the establishment of quarter corners on section lines.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

FIG. 100. *Method of numbering sections from 1796 to date*

In the earlier days public land-survey plats, showing the townships and sections, were prepared in the land office. The plats were then taken to the field and the lines laid out and marked on the ground. It was soon discovered that the platted lines would not fit on the ground, and it became apparent that adjustments would be necessary to make a rectangular system of surveys fit the surface of the earth, which is approximately that of a sphere. The platting of the subdivisions before field work had to be abandoned, the field work done first, and the plat then made according to the conditions found on the ground.

As various discrepancies arose from time to time in the field, their correction and adjustment were governed by instructions issued from the General Land Office and by acts of Congress. In order to systematize the corrections necessary to equalize curvature, correction lines were established. Survey lines from the south would stop at the correction line, and lines on the north start the proper distance apart. It was finally determined to place correction lines at regular intervals and thus provide a systematic rather than haphazard method of correction. In 1881 a regulation was adopted which is still in force, providing for curvature correction by standard parallels and guide meridians run every 24 miles. The lines divide the area to be surveyed into tracts 24 miles square. The correction for curvature is made on the north side of the 24-mile tract at the standard parallel.

The rectangular system of land surveys may be considered as developing from 1785 to 1881. Previous to 1881 the method was altered every few years, the most radical alterations taking place from 1785 to 1805. After this time the changes made were for the purpose of eliminating

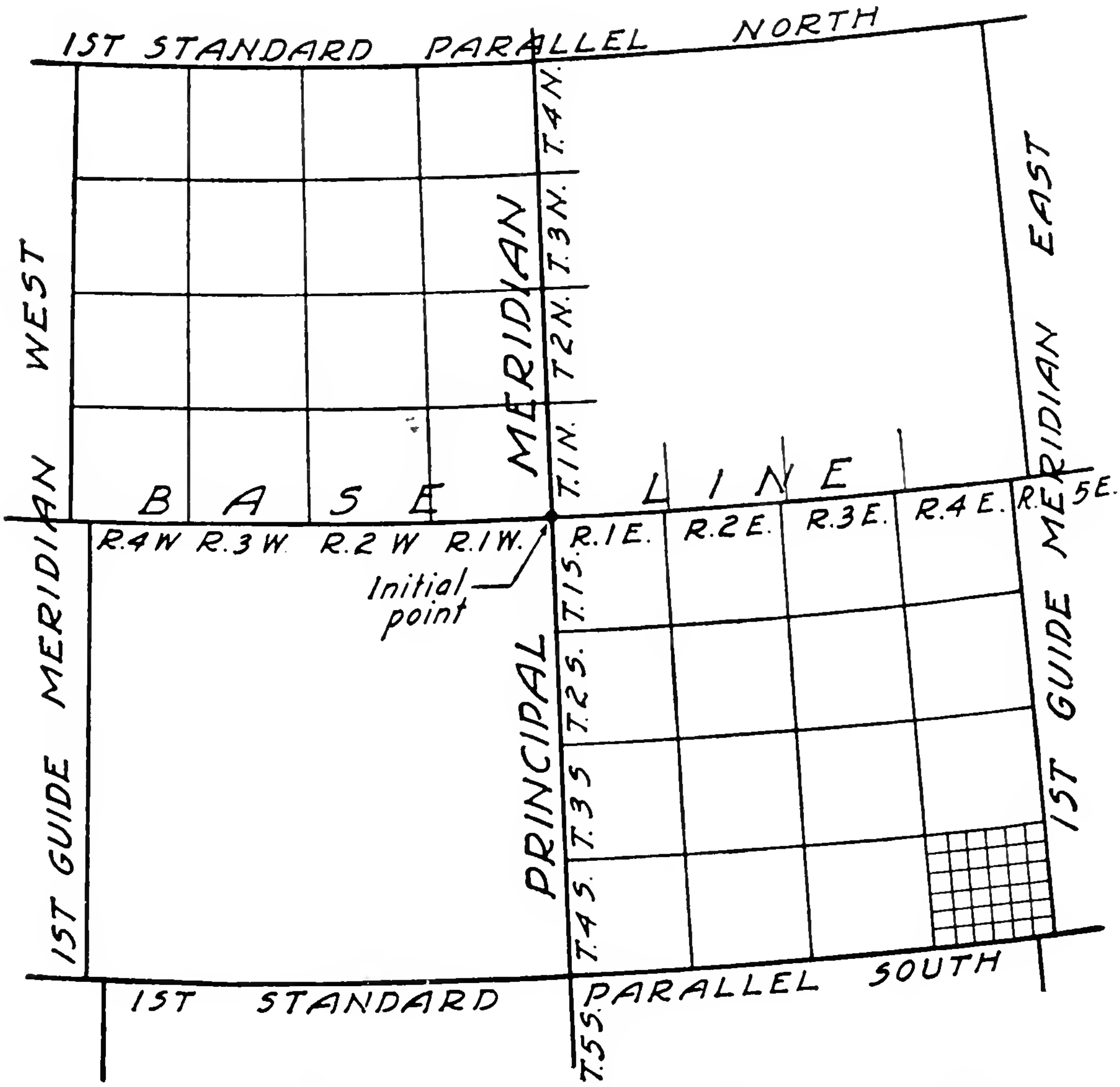


FIG. 101. *Showing the position of the initial point, base line, principal meridian, standard parallels, guide meridians, townships, and sections*

the discrepancies due to curvature. Since those were practically all provided for in 1881, the rectangular system has been uniform since that date.

Initial point. After the adoption of the rectangular system, when it was necessary to survey a tract of land widely separated from any other surveyed lands an initial point was selected and approved by the Commissioner of the Land Office. This point was carefully monumented and its position located by astronomical observations (Figs. 101, 102).

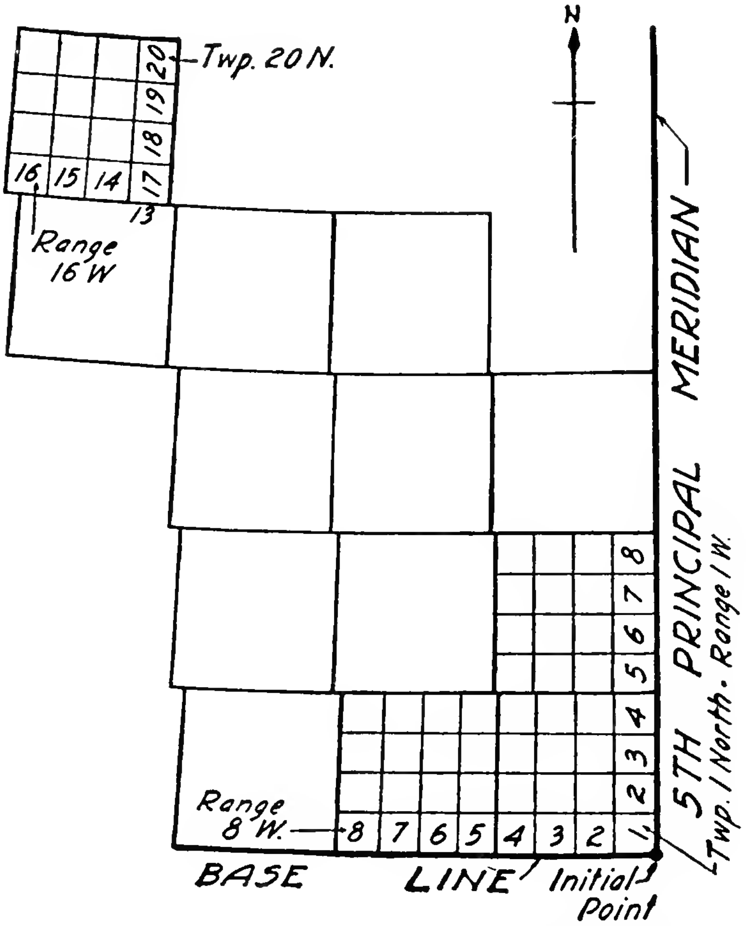


FIG. 102. *Showing the same information as Fig. 101, but the principal meridian and base line have been run in only one direction from the initial point*

Base line. From the initial point a line, known as the base line, was run due east or west or both east and west, the length of this line being determined by the extent of the lands to be surveyed.

Principal meridian. From the initial point a line was run due north or due south or both north and south, known as the principal meridian, the length of this line also being determined by the area of the land to be surveyed. In the beginning a start was made to number the principal meridians from east to west, but it was found that it was not feasible to keep them in consecutive order, and the system was abandoned after six numbers had been used. The method of giving the principal meridian a proper name was then adopted, and now the principal meridians may be considered as having special names, including the six that were numbered. They are designated as First, Second, Black Hills, and Boise, for example, the name of the meridian implying the corresponding initial point and base line. Twenty-seven principal meridians have been established in the United States.

Standard parallel. Beginning at the initial point, on the principal meridian, lines are run east or west every 24 miles parallel to the base line and of such length as the area to be surveyed may call for. These lines are known as standard parallels and are numbered consecutively north or south, from the base line.

Guide meridians. On the base line and on each standard parallel every 24 miles, beginning at the principal meridian, lines are run due north as far as the next standard parallel. These lines are known as guide meridians and are numbered consecutively east and west, beginning next to the principal meridian.

Township exteriors. On the completion of the standard parallels and the guide meridians, the boundaries of the townships are surveyed, the surveyors beginning at the southwest corner of the 24-mile area and resurveying the first 6 miles of the standard parallel, then running due north 6 miles, then running west on a random line to the corner which was set on the principal meridian 6 miles from the initial point. Since some errors will be involved, the distance is measured between the actual corner and the point of intersection of the random line and the principal meridian. The true line is then run from the principal meridian back to the northeast corner of the township. The line north is continued from the northeast corner 6 miles and again run west to the principal meridian. In this way the townships are extended north. The intersection of the east side of the north township with the standard parallel is marked "closing corner." Owing to the convergence of the meridians, this point is less than 6 miles from the principal meridian. The next tier of townships is carried north in the same manner, and when the east line of the third tier of townships is carried north, at the northeast corner of each township a line is run east as well as west to establish the north boundary of the fourth or east tier of townships, since the guide meridian forms the east boundary of that tier.

At the time the base line, principal meridian, standard parallel, guide meridians, and township corners are surveyed, all corners, including the section and quarter-section corners, are established on these lines. The legal width of a township, 6 miles, is correct on the south side of the 24-mile area, but on the north side of the area the township widths are less than 6 miles because of convergence. The line that is run east or west to the corner that has previously been established is a random line, and no permanent corners are placed upon it. As soon as the location of the random line is known with reference to the corner which is to be intersected, the line is corrected and the corners established on the true line.

Convergency due to curvature increases with the latitude and is as follows for a tract 6 miles wide and 6 miles long on the indicated parallels:

Lat. 44.	Convergency	70.1 lks.
Lat. 45.	Convergency	72.6 lks.
Lat. 46.	Convergency	75.2 lks.
Lat. 49.	Convergency	83.5 lks.

Offsets to locate a parallel when run as a prolongation of a line having an angle of 90° with the meridian at the starting point would be as follows for a location near 45° North Latitude:

1 mile	0.67 ft.
2 miles	2.66 ft.
3 miles	5.99 ft.
4 miles	10.65 ft.
5 miles	16.64 ft.

Numbering of townships. Each tier of townships east and west is numbered consecutively from the base line, the direction from the base line being indicated after the number, the tier being designated as township. Each tier of townships north and south is known as a range and is numbered consecutively east and west from the principal meridian, the direction from the principal meridian being indicated after the number. For example, township 20 north, range 18 west, indicates that the location is 20 townships north of the base line and 18 townships west of the principal meridian.

Sections. The division of the township into one-mile tracts or sections is known as the subdivision of a township. The sections are laid out by the method of beginning at the southeast corner of the township and resurveying 1 mile of the south line of the township, then running north 1 mile parallel to the east line of the township, then running east on a random line to intersect the township or east boundary of the section. When the location of the random line with the section corner 1 mile north of the southeast corner of the township is found, correction is made, and the north line of the section is then established from east to west. By the same method each additional section is laid out until the north line of the township is reached. In the extension of the west boundary of the section north, each is 80 chains or 1 mile except the one which intersects the north boundary of the township. It may be either longer or shorter than 80 chains. Since this line is parallel to the east boundary of the townships, the sections are all a mile wide except the tier of sections next to the west township line, which may be more or less than 80 chains in width. Owing to this system of laying out the sections, the north and west tier of sections in each township may be more than one mile square, but usually are less than a mile. The south and east halves of these sections contain the required acreage, but the north and west halves usually contain less and are numbered as lots with the exact acreage specified. Field errors not shown in the records are the cause of sections not containing exactly 640 acres. The

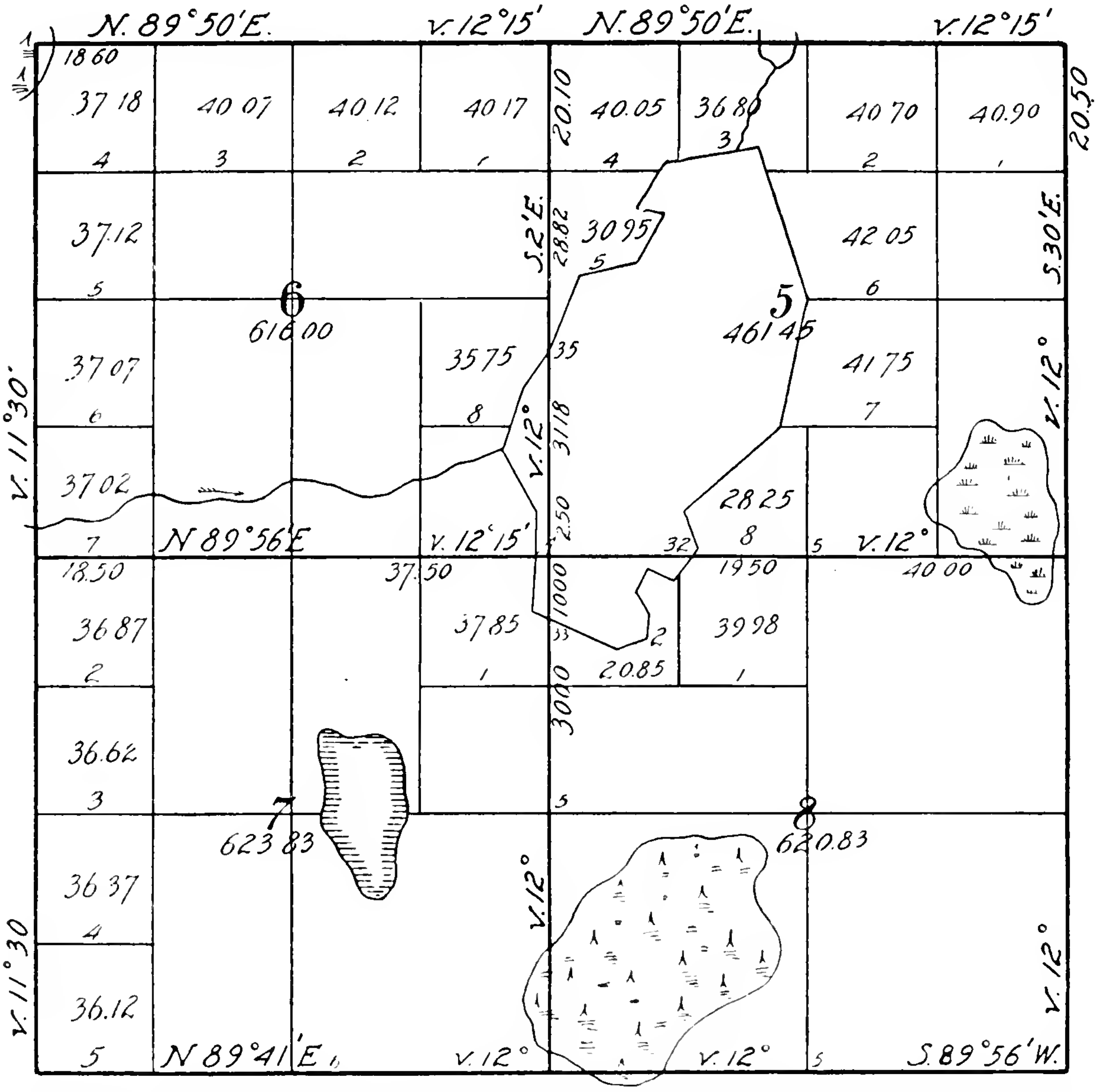


FIG. 103. *Plat of four sections in the northwest corner of a township, showing lots, meander lines, topographic and other data recorded in the original township plats made by the deputy surveyor on a scale of 2 inches to a mile and filed with his notes*

necessity of designating the lots is due to the errors caused by both curvature and the field work. (See Fig. 103.)

The west boundaries of the sections are not true north lines, because they are run parallel to the east township lines. The greatest discrepancy in the area of a section, due to curvature, is in the northwest corner of the township lying immediately south of the standard parallel. Curvature corrections applied at the standard parallel cause an offset in the north-and-south lines. This offset is noticeable on the north-and-south section-line roads crossing in the vicinity of a standard parallel. (See Figs. 101, 102.)

The following is an exact copy of the notes from an original field book of a land surveyor. Note that the distance in chain is indicated by figures at the left. Note also the abbreviations and other descriptions.

T. 143 N.–R. 36 W.–5 P. M.

80 Set a post for corner of Secs. 11, 12, 13, and 14, from which
Dead Y Pine 16″ dia. N. 90° W. 109 lks.
“ “ “ 15″ dia. N. 10° E. 91 lks.
No other trees near.
Land rolling — Soil 3d rate.
Timber pine. Undergrowth aspen.
East on a random line between sections 12 & 13. B. 12° 30′ E.

23.50 Lake Itasca. Set a post for temp. cor. to frac'l Secs. 12 & 13 to obtain distance across lake, I sent my flagman around to the E. bank thereof, who sets the flag in the random line between Secs. 12 & 13. I now run a base south 3.50 chs. to a point from which the flag bears N. 82° 30′ E. which gives for distance across the lake and on random line between Secs. 12 & 13, –27.34 chs. to which add 23.50 chs. makes

50.84 To the flag on the E. bank of lake.
Here set post for temp. cor. to frac'l Secs. 12 & 13.

79.95 Intersect E bdy. 17 lks N. of cor. to Secs. 12 & 13 from which cor. I run N. 89° 53′ W. on a true line between Secs. 12 & 13. Same va.

29.11 Set a post for cor. to frac'l Secs. 12 & 13 from which
Y Pine 18″ dia. S. 74° E. 74 lks.
Y Pine 20″ dia. N. 61° E. 98 lks.

T. 143 N.–R. 36 W.–5 P. M.

56.45 Set a post for cor. to frac'l Secs. 12 & 13, from which
Ash 6″ dia. N. 30° W. 11 lks.
Ash 6″ dia. S. 69° W. 15 lks.
The point for ¼ Sec. Cor. being in lake, it cannot be established.

79.95 The cor. to Secs. 11, 12, 13, & 14.
Land rolling — soil 2d rate and 3d rate.
Timber aspen and pine.
Undergrowth same.
North between Secs. 11 & 12–B. 12° 30′ E.

Limit of errors. Random lines must intersect township exteriors within 3 chains north or south of the required corner. The north lines are 80 chains in length except on the north side of the township, where they must be within 160 links of the theoretic length. The north random line must fall 50 links east or west of the corner on the north township line. East random section lines must intersect 50 links north or south of the required corner.

Instruments. In the beginning practically all lines were run with a magnetic compass, but the law of 1881 limits the use of the compass to section lines and requires the use of solar instruments on all other lines, and also requires a frequent checking of these instruments by polar observations. All measurements are kept and recorded in units of the 66-foot chain.

Irregular sections. In the mountainous regions of Nevada, California, and Oregon the Secretary of the Interior may vary the shape of the section somewhat from the rectangular to suit the country.

Meandering. The surveying of waters is known as meandering and the line as a *meander line.* A river or lake that is navigable is surveyed by an irregular line which is supposed to follow the high-water line along either shore or around the lake. The distance and direction of each course in the line is given, and wherever the line intersects a section line a meander corner is established. Rivers that are navigable or 3 chains in width and tidewater streams are meandered. Shallow streams without permanent banks are not meandered. Navigable lakes or deep ponds containing 25 acres or more are meandered. The determination of whether or not the water is navigable and the location of the high-water line are left to the judgment of the surveyor. In wet seasons many streams and lakes are improperly meandered, and in dry seasons many meander lines are omitted which should be run. These errors are due to lack of information at the time the country is surveyed. The general appearance at the time of the survey is the only guide to be had in the determination of the condition of navigable waters.

Riparian rights. Riparian rights are the rights of landowners across the meander line. While possession extends only to the meander line, the landowner has some rights as owner to the shore line and on flats or unsurveyed islands between the meander line and the center of the stream channel. He cannot interfere with navigation, but he has control of the hay, sand, gravel, ice, etc., across the meander line from his possessions. Riparian rights are frequently the cause of disputes, and many court decisions have been rendered with regard to them.

Marking lines. In surveys through timber, trees through which the line passes are blazed where the line enters and leaves and several trees within 50 links on either side of the line are blazed. The blazes are placed quartering toward the line on two sides, and the farther the tree from the line the closer together the blazes. Where the timber is not larger than 2 inches in diameter, blazes are omitted, but the bushes are bent toward the line by being struck with an ax with sufficient force to cause them to grow in an inclined position. A complete description of all natural or artificial objects on either side and visible from the line is recorded by the surveyor, and he also classifies the soil into first, second, third, and fourth class and gives a description of the size and kind of timber. The variations of the needle for each line run are recorded.

Section corners. The object of land surveying is to establish corners, and all corners should be carefully located and plainly marked. Corners should be witnessed by bearing trees if suitable trees stand within 300 links. The intention of the law is plain with regard to making surveys and setting monuments, but in unsettled country the scarcity of supplies and materials and frequently the carelessness of contractors resulted in only partial compliance with the requirements, and many errors occurred in the work.

Methods and materials used in building section corners. The following materials are used for section corners:

Fig. 104. *Post which served as section corner thirty-five years*

Stone with pits and mound of earth
Stone with mound of stone
Stone with bearing trees
Post with pits and mound of earth
Post with bearing trees
Mound of earth with deposit and stake in pit
Tree corner with pits and mound of earth
Tree corner with bearing tree

Fig. 105. *Markings on one of the bearing trees for the section corner shown in Fig. 104*

RESURVEYS

Object of resurveys. Owing to poor marking of lines and the rapid obliteration of corners, numerous surveys are required to determine the location of original corners. Such work comes under the head of resurveys. The sole object of a resurvey is to locate and find the original corner. The law and the supreme court decisions are explicit on this point, that in a resurvey the original corner must be located if possible. It is not a question of where the corner should be, but of where it actually was placed. Even though gross errors may have occurred in the original work, the old corner, if found, must be accepted as correct. In a resurvey the complete record of the original survey should be obtained, and the regulations governing at that time should be taken into consideration. Then as many corners as practicable should be found, and, with these to work from, the original survey should be duplicated. After the approximate location of the corner has been determined by careful measurement, search should be made for it. The records will indicate the nature of the original corner. Digging should not be attempted until this information is available. Digging should be done with a spade. A slice not over an inch thick should be cut by the method of passing the blade of the spade parallel to the surface. As each layer of the earth is removed, the uncovered surface should be carefully inspected for indications of the corner. Frequently rotten wood, iron rust, or evidence of a pit or hole in the ground will be the only indication of the corner. Great care should be exercised not to destroy these evidences by careless digging or deep cuts.

According to court decisions surveyors have no more authority than any other persons to determine boundaries and corners. Their judgment and experience will assist them in studying the records, measuring old lines, and identifying the original corner when found. In case the original corner cannot be identified, it should be replaced by duplication of the old survey as nearly as may be practicable, and a new corner should be placed where the measurement would indicate that the old corner stood.

Corners as evidence. In the locating of a tract of land, corners that can be identified on the ground control regardless of bearing or distance. Distance is better evidence than bearing. Areas can be used only as a last resort and have little weight in the determination of boundaries. Corners and lines identified on the ground are better evidence than plats or written descriptions. A great many court decisions have been rendered relating to disputed land lines. These decisions usually are based on the actual proof of what has been considered as the boundary rather than on surveys that have been made by surveyors who are unfamiliar with the locality or who have not been able to identify the original lines and corners. A long-established fence that has been accepted and regarded as the line is better evidence of the actual boundary than a survey made after the monuments of the original survey have disappeared. When disputes occur as to land lines, it is advisable to attempt to adjust them by considering all of the local conditions and finding actual evidence of the line rather than to go into court. It is impossible to determine even reasonably correctly the point of the original corner after it has once been destroyed. The idea that a surveyor can set up an instrument and locate a line or corner is true only when he has sufficient original corners to work from.

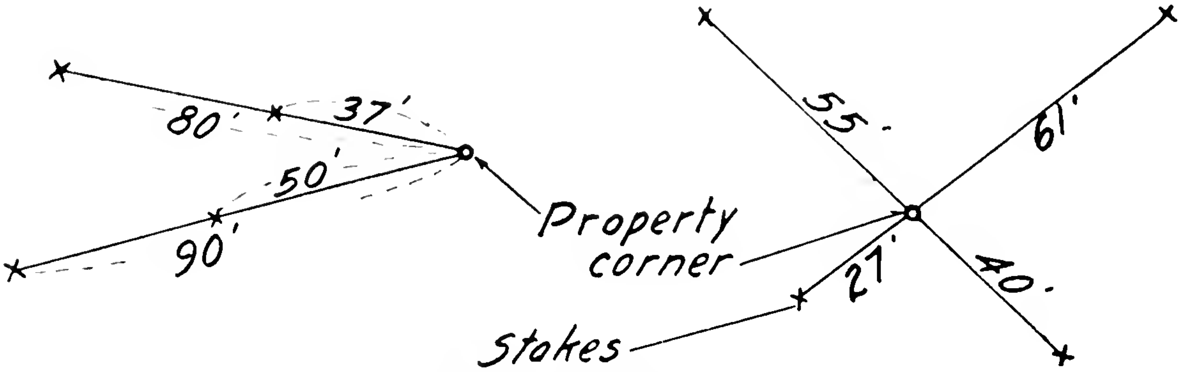


FIG. 106. *Showing the methods of setting reference stakes for relocating a section corner which will be destroyed by grading. Either method can be used and the stakes set at any angle. The only instrument required is a tape line. Reference stakes should be driven to the surface of the the ground and located at sufficient distance from the corner so that they will not be disturbed. As soon as the work is completed the corner should be replaced. If the stakes are carefully set, measurements are not necessary, but a measurement is a check in case one of the reference stakes is lost*

Then he will probably fail to make a proper location, as there may have been an error in the original survey and the corner may not have been placed properly. Land boundaries are located properly only when the original corners are in position. Any boundary determined under any other conditions is probably inaccurate, and it may be entirely out of the question to reëstablish it in its correct location.

Preservation of corners. Landowners should take a greater interest in the preservation of survey monuments marking their boundaries. When grading or excavation work is done, survey monuments are frequently in the way and must be removed, but by a system of reference points a monument can easily be replaced on the completion of the work.

Stakes and other monuments that have decayed or are in danger of being destroyed should be replaced by permanent monuments while the old ones are still visible. A monument should be permanent and easily found. It should be so constructed that it will not be destroyed by road machinery. The following materials and methods have been used for replacing monuments: (1) Wooden posts set deep in the ground may be used. Rotten wood and the point can be found for many years if the soil has not been disturbed. (2) A large bowlder with a cross cut on its top can be used, but it is subject to removal by road machinery or may be destroyed by blasting. (3) A cut stone post is easily identified, but may be torn out by a road-grader. (4) Four- or six-inch sewer pipe 30 inches long, filled with concrete, makes a permanent corner easily identified, but it may be torn out with road machinery. (5) A special cast-iron post is easily identified, but may be pulled out in road work. (6) A brick pier 8 inches square and set deep in the ground is easily identified and hard to destroy, since the top may be broken or taken off without disturbance of the lower part. (7) Burnt charcoal, brick, lime, or glass placed under the corner makes it possible to identify the corner location in case the monument itself is destroyed. (8) In excavation work the location of the corner may be preserved by means of boring with a two-inch auger to a depth below the point of excavation and filling the hole with material such as lime, cement, plaster of Paris, or sand which can be easily identified after the excavation work is completed and a permanent corner can be set. (9) Old gas pipe, from ¾ to 1¼ inches in diameter cut 30 inches long, makes a good corner. It can be driven with a sledge in soft ground and placed with an auger in hard ground. After the pipe has rusted out, large scales will be left by which the point can be located. (10) Old boiler flues or pipe 2 or 3 inches in diameter, set in the ground 3 feet deep and filled with concrete, make an excellent corner. When the metal rusts away, the concrete core remains in place.

BOUNDARIES

National boundaries. Boundaries limiting governmental jurisdiction are indicated in various ways. An international boundary may be a natural feature of topography, as a river, the crest of a mountain range, or a large body of water. Latitude and longitude are frequently used. Topographic features determine boundaries fairly accurately for specifications in writing, but until surveys are made they are indefinite on maps and are frequently indefinite on the ground. Latitude and longitude are definite both on maps and in written descriptions, but have no meaning on the ground until surveys have been made and monuments established. After monuments are erected, any boundary is definite. The north and south boundaries of the United States include both topographical and latitude designations (Fig. 107).

State boundaries. State boundaries are topographic features, land-survey lines, or a line run and monumented as a boundary. States which have had their boundaries determined since the land surveys were completed usually have their boundaries conforming to certain township lines and corners. States which have used topographic features, such as mountain crests, have later found it necessary to survey and monument a definite boundary on the crest. Lakes make a definite state boundary. Rivers are the cause of complications, owing to the formation of islands and the cutting off of bends.

County boundaries. In unsettled regions of the country county boundaries are natural features of topography and lines surveyed and monumented as boundary lines. As a rule the counties finally make their boundaries conform to land-survey corners and lines unless they are sharply defined by topographic features.

Government reservations. Government reservations such as Indian reservations, military reservations, national forests, etc., are bounded by natural features of topography in unsurveyed country. Land-survey lines are used where the land has been surveyed, and where there are no land-survey lines or satisfactory topographic features, metes and bounds are used with proper monuments around a part or the whole of the reserve.

Foreign land grants. Spanish land grants and French land grants have their boundaries determined by metes-and-bounds surveys, but later many of these have been subdivided by private owners in conformity with the rectangular system.

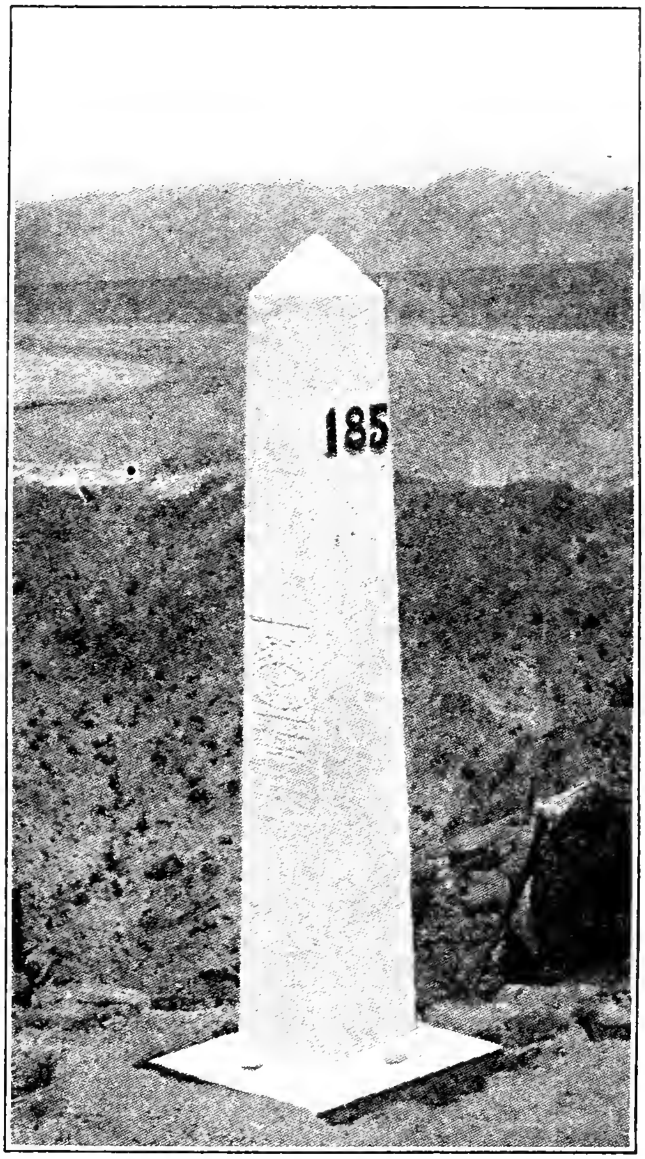


FIG. 107. *Monument 185 on the International Boundary between the United States and Mexico (monument made of cast iron)*

ADMINISTRATION

National. The administration of the public land surveys is vested in the General Land Office, which is a bureau of the United States Department of the Interior. The Commissioner of the Land Office has general charge of all public lands, both as to their surveys and as to their disposal to private individuals or corporations, and he acts as a court of appeal on disputed points. For convenience in the administration of the law relating to surveying and the classification of public lands, offices were established in each state or territorial organization and all survey work relating to public lands was handled through these offices, a copy of the surveyor's plats and field notes being filed there. As soon as the lands included in the territory under the jurisdiction of any such office were surveyed, the office was abolished and the land records turned over to some state official appointed by state authority to receive them.

Local land offices. Local land offices are located at central points where there is surveyed public land. The officials of these offices are the register and the receiver. The local land offices have jurisdiction over public lands and pass upon applications for lands under the public land laws. As soon as all public lands have passed into private ownership in a given territory, the local land office for that territory is abolished.

Contract surveys. The actual work of surveying was formerly done by contractors who bid on the work within certain limits, the surveyor in charge of the work on the ground receiving an appointment as Deputy United States surveyor. On completion of the survey, notes and records were filed with the surveyor-general and a statement sworn to that the work had been completed according to contract. After it was too late it was learned that much of the survey work was not properly done in the field, and a system of inspection was established. The inspectors were in the regular employ of the government and examined all contract work by going into the field and rerunning part of the lines, the contractor being required to wait for his pay until the report of the inspector was filed. In late years considerable land-survey work has been done by surveyors who are in the regular employ of the government.

Methods of acquiring government land. Regulations relating to homestead rights are changed from time to time by acts of Congress. Copies of the regulations in force at any time may be secured without cost from the Commissioner of Public Lands in Washington, D. C.

There is a special act, known as the Desert Land Law, which provides for granting larger areas in the arid states than are granted under the homestead laws. There is also a provision permitting individuals to secure timber and stone claims on surveyed lands without actual possession of the land. In the western part of the United States where precious metals are found, mineral areas are withdrawn from homestead entry and mining claims are taken in place of homesteads. The amount of land and the conditions under which mining claims can be taken vary somewhat with the districts. Regulations relating to those claims may be secured from the Commissioner of the Land Office.

LAND DESCRIPTIONS

Metes and bounds. The following is a good example of a description of a tract of land located by metes and bounds:

> Being Survey No. 13327 of one hundred and forty-one acres of land, a part of Military Warrant No. 5948, the whole thereof being for five hundred acres issued in favor of John Hobson. On the waters of the West Fork of Brush Creek, beginning at two White Oaks and Hickory, southwest corner to Charles Lewis Survey No. 3661, thence with this line south sixty-seven degrees east one hundred and thirty-one poles (crossing a large branch) to two Black Oaks, thence south twenty degrees east one hundred and three poles, crossing the Marble Furnace Road to two Honey Locusts, a Walnut, and a double Hickory on said branch at the mouth of a small branch, thence south sixty degrees west one hundred and fifty poles to two Black Oaks and a White Hickory, thence north thirteen degrees west sixty-three poles to two Bur Oaks and a Red Oak; easterly corner to a survey of said Vinsonhaler No. 8367, thence with this line north seventeen degrees west sixty poles to two Hickory from one root, thence with this line north forty-five degrees west sixty-two poles to four White Oaks, northwest corner to said Vinsonhaler No. 8367, thence with this line south fifty-one degrees west fifty-three poles to a Hickory, corner to said Vinsonhaler and southeast corner to Survey No. 2550, thence with the line of the same north thirty-one and a half degrees east one hundred and twenty poles (passing the Northeast corner of said Survey No. 2550) to three White Oaks, thence south sixty-seven degrees east thirty poles to the beginning.

Rectangular system. Under the rectangular system a land description may be written:

"E.½, N.E.¼, N.E.¼, SEC. 24—T. 13N.—R. 21E.—5 P.M."

This description applies to only one tract in the rectangular system and means 20 acres on east side of the northeast quarter (or 40) of the northeast quarter section (or 160) of Section 24, in Township 13 North, of range 21 East, of the fifth principal meridian. In deeds and other important legal descriptions the description should be completely written out and the above abbreviations should be placed in brackets. While the written description is not necessary, it prevents error and should be used where accuracy is required. The names of the county and state, while not necessary, should always be given.

SUMMARY

There are two classes of land surveys, original and resurveys; also two methods of making original surveys, metes and bounds and the rectangular system.

The rectangular system has been used in the United States since 1785. It provides for laying lands out in square tracts, and, as the surface of the earth is that of a sphere, many of the errors in land surveys are caused by the attempt to fit a rectangular system to a curved surface. Regulations governing the rectangular system were frequently changed from 1785 to 1881. Since 1881 errors due to curvature are confined and corrected within tracts of land approximately 24 miles square. The actual acreage in legal subdivisions of land varies from the theoretic acreage because of errors in field work.

Corners set by a United States deputy surveyor and approved by the Land Office must be considered as correct, even though it can be shown that errors were made in the original survey.

A resurvey is for the purpose of locating the original corners and lines. In a resurvey the surveyor cannot change the location of an original corner.

Disputes as to land lines carried to the courts are decided entirely on the proof offered. Surveys are not considered as proof unless it can be shown that they were the means of locating the original corner. Fence lines that have been accepted as correct are better proof than surveys after the original corners have been destroyed.

Meander lines are boundary lines lying between private lands and navigable waters.

Riparian rights are the rights of landowners across the meander line.

Land monuments should be carefully preserved.

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Timber and Stone Act. U. S. Land Office, Washington, D. C.
Vacant Public Lands. U. S. Land Office, Washington, D. C.

PART II. MATERIALS OF CONSTRUCTION

CHAPTER VII

WOOD

Wood has been the universal material of construction on the farm, and it will be extensively used for a long time in the future, although it is being replaced by clay products, concrete, and concrete and steel.

Source of supply. Wood suitable for building purposes is of two kinds: soft and hard. It is obtained from the bodies of two classes of trees known as *conifers* and *broad-leaved.* The conifers have needlelike leaves, are cone-bearing, usually evergreen, and furnish the greater part of the soft-wood lumber. Trees of this type are the white pine, Norway pine, fir, spruce, redwood, cedar, cypress, hemlock, and others. The broad-leaved trees are usually deciduous and nut-bearing and produce hard wood. Trees of this type are the oak, hard maple, hickory, walnut, ash, elm, beech, gum, and various others. Both conifers and broad-leaved trees are pretty generally distributed over the timbered areas of the United States. It must not be understood that a tree can be classified as soft or hard simply from the shape of its leaves or the fact that it is or is not an evergreen. Tamarack is a conifer, deciduous, and produces soft wood; the southern pine is a conifer, evergreen, and produces hard wood; the poplar is broad-leaved, deciduous, and produces soft wood; and the live oak is broad-leaved, evergreen, and produces hard wood.

Tree growth. Trees which produce lumber grow from the pith or heart outward in a series of concentric rings (Fig. 108). Each ring represents one year's growth; the light inner part is soft and weak and represents the spring growth;

the dark outer part is dense and strong and is the summer growth. The rings decrease in width as they approach the outside of the tree. The weakest, softest zone is the last-growing part, found immediately inside the bark and known as *sapwood*. The densest, strongest part is found in the interior and is known as *heartwood*. The change from sapwood to heartwood is gradual from the bark toward the heart.

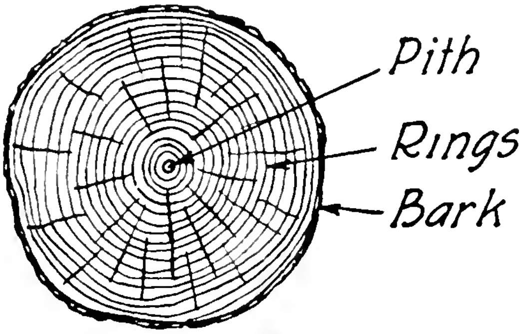


FIG. 108. *Section of log showing growth of tree*

Grain. A *close-* or *fine-grain* wood is one in which the rings are relatively narrow; an *open-* or *coarse-grain* is one in which they are wide. A *straight-grained* timber is one in which the grain runs parallel to the length, and a *cross-grained* timber is one in which the grain is twisted, distorted, or runs at an angle to its long side. A straight-grained timber is stronger and will split in more uniform sections than one that is cross-grained. In Fig. 109 *A* is sawed parallel to the grain, and *B* across the grain.

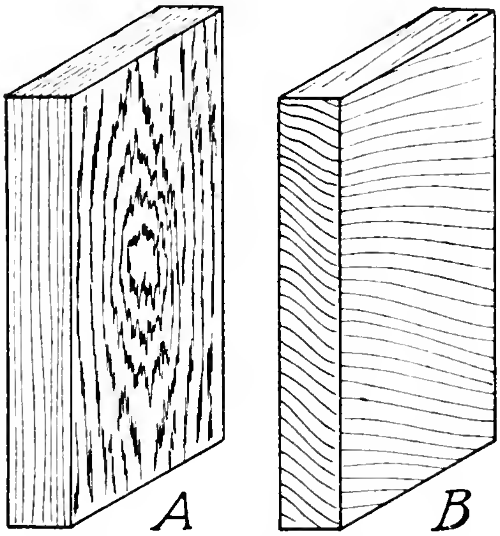
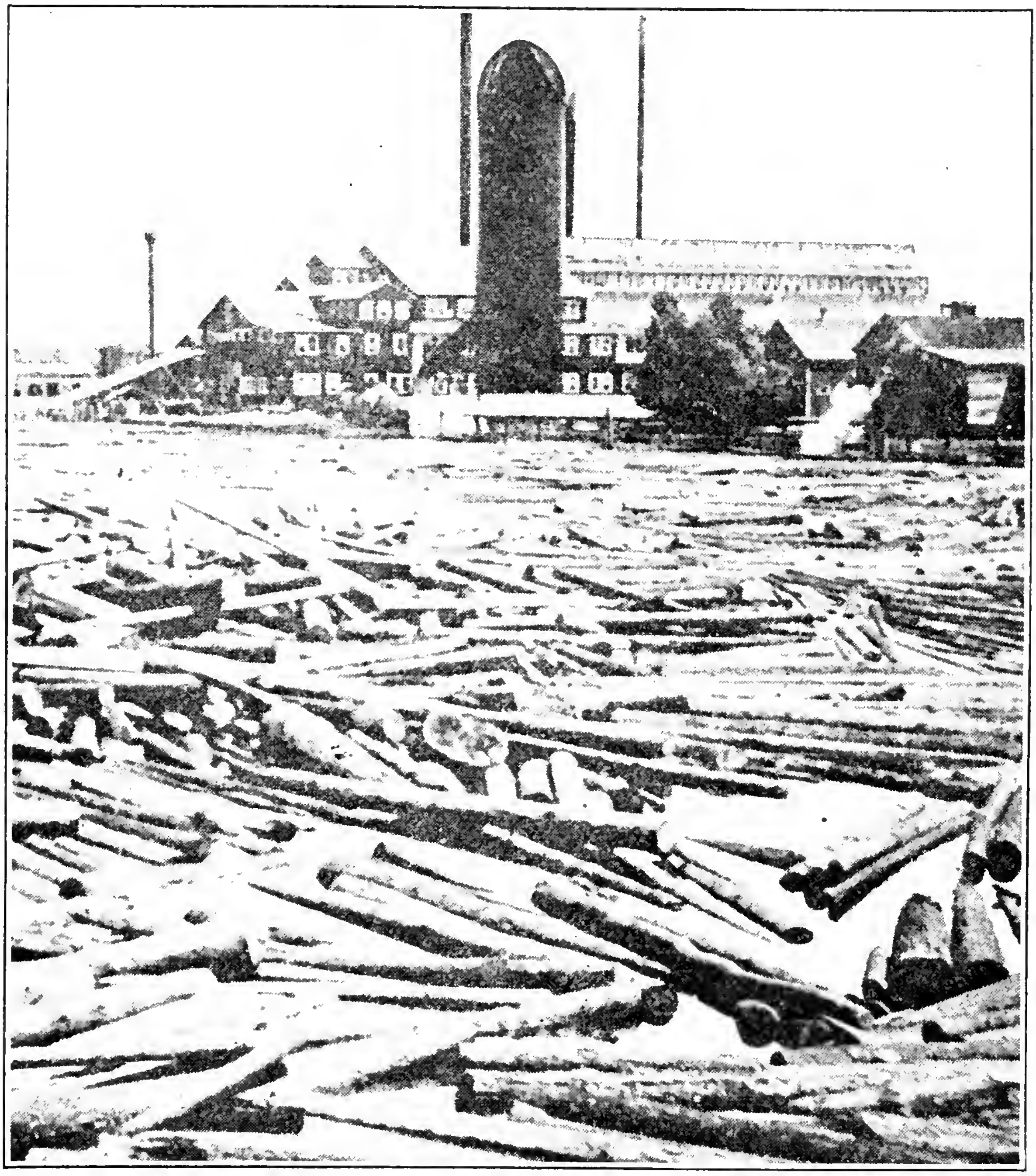


FIG. 109. *Grain of wood*
A—Straight, slash, or flat grain
B—Quarter-sawed or vertical grain

Lumber production. The pioneer selected the most suitable trees near his building site, cut them into lengths with an axe, notched the ends, and laid them up round, or, by the aid of a broad axe, flattened one or more sides by hewing. If a few flat light pieces were needed for finish, they were made by *whipsawing*, which consisted in cutting a log lengthwise with a long saw operated by hand. This method of building was laborious, wasteful of timber, and fell into disuse as soon as power machinery became available for the working of wood.

The present process of transforming a tree into usable lumber is nearly uniform regardless of the locality or the final distribution of the product. The actual operation of lumbering may vary according to locality and quantity to be handled. In farming communities where the timberland is in small tracts merchantable logs are cut in the winter and hauled to the mill or railway. When there is a home or neighborhood demand, logs suitable for the purpose at hand are cut and hauled to a convenient point, where a portable sawmill is set up and the required sizes of lumber sawed and used as they come from the mill.

The bulk of the lumber is produced in the forest areas, in advance of farm improvements, by companies that operate on an extensive scale. Camps are built in the late summer to house large crews of men, who begin in the early fall to fell the trees and cut the logs. Teams of horses attached to one end of the logs drag them to the foot of the hill or slope, where they are piled on timber foundations called *skidways*. Wide roads are cleared down the draws and along low ground to the nearest stream. As soon as the snow falls it is tramped down in these roads, sprinkled with water, and permitted to freeze, thus making a smooth ice road on which the sleds can run. Over this road the logs are all hauled and piled on the stream bank by the time of the spring thaw. When the streams are clear of ice and while the spring floods are on, a number of logs are rolled into the stream each day and permitted to float with the current. Crews of men patrol the stream, breaking up jams or pushing out logs that may lodge, and keep the whole mass of logs in the current and moving. The floating of the logs is known as *driving*. Small streams are made available for driving by temporary dams constructed a few miles apart along their course to hold back the water, which is released only as logs are being rolled into the stream. The logs are floated loose until they reach the mill, where they are caught and held by a *boom*, which is a series of logs chained together and stretched across the stream (Fig. 110). From the cutting of the tree until the mill is reached, the cylindrical shape of the log and the force of gravity are utilized to the greatest advantage to keep it moving by selection of a route of travel that is downhill. Skidways are located at the foot of the slope, the foundation being at least as high as the top of the sled so that the logs can be rolled onto the load with the minimum effort. The roads chosen are slightly down grade or on the level. In mountainous regions logs



After Minnesota Forest Service

FIG. 110. *Sawmill and floating logs held by boom*

are rolled down steep slopes, slid down timbered chutes, and floated down on water confined in timber flumes. In countries where the topography does not permit of the hauling to streams on ice roads or the temperature does not go low enough to form such roads, special narrow-gauge railroads are built for hauling the logs, which may be brought to the loading place by long cables and winding engines and loaded with derricks and other power appliances. In the earlier days, and to a limited extent at the present time, rafts were formed on large streams by means of logs placed side by side and held in position by timbers and wooden pins. These are floated or towed to the mill, which is usually at the site of the final disposition of the lumber.

From the time the log reaches the mill until it is ready to be piled in the yard in the form of commercial lumber, it is handled almost entirely by mechanical means, the mill men giving their attention to the operation and care of the machinery. The log, if it is to be cut in thin lumber, may be sawed in two ways: by *slash* or *straight sawing* (Fig. 111), in which the entire log is cut by passages of the saw parallel to the long axis; and by *quarter sawing*, in which the log is first divided into quarters by the saw, each quarter being cut into planks either radially from the center or parallel to one side. By the first method the greatest width of boards can be secured, but each will have sapwood at the edges and heartwood at the center, will not dry uniformly, and is therefore liable to warp and shrink. This is considered the poorest method of sawing. The greater part of the grain or annular rings are parallel to the face, and the lumber is known as flat, slash, or straight-grained. In the second method shrinking and warping are reduced to a minimum and the

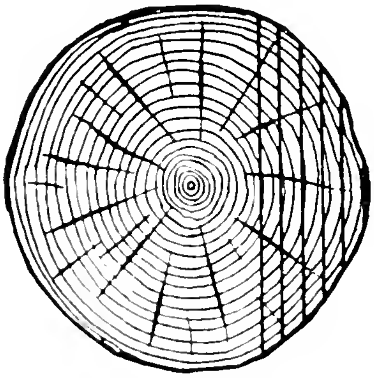


FIG. 111. *Boards produced by straight sawing*

wearing is increased, as the end of the hard element of the wood is exposed at the surface. The radial method of quarter-sawing is considered the best. The grain or annular rings are between 45° and 90° to the surface, and it is known as quarter-sawed or vertical-grain lumber (Fig. 112).

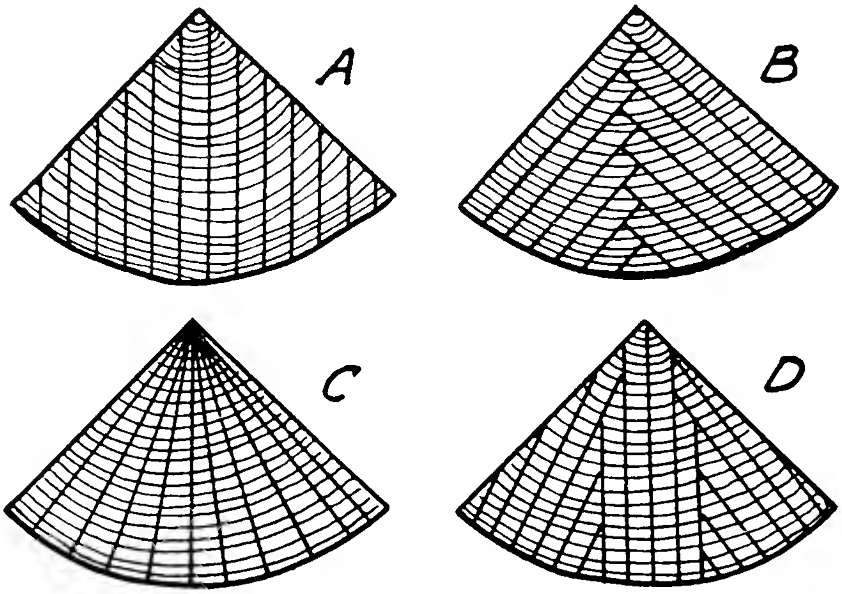


FIG. 112. *Boards produced by quarter sawing*

From the saw the *slab*, which is the round part, including the bark and sapwood, that is cut from the sides of the log when it is reduced to a square or rectangular shape, may go to the shingle and to the lath saws, where all the usable parts are cut into shingles or lath. The refuse is used for fuel or destroyed in the refuse burner. The body of the log is cut into such sizes as its quality will admit and meet commercial requirements. From the saw such of the lumber as is necessary goes to a saw table, where it is trimmed of bark and worthless sapwood that was not taken off with the slab. It all goes to the sorting table, over which it is moved at right angles to the long center of the table by mechanical conveyors. Near and across the end of the table where the lumber comes on is a series of small saws so arranged that when not in use,they remain under the table, but can be put in operation above the table at the will of the operator. By means of these saws the operator can square either end, cut off a defective end, or reduce to some one of the standard commercial lengths any piece passing him. Each piece is then inspected by a grader, who marks on it the grade, after which the pieces, according to dimensions and grade, are taken from the table by laborers, placed on hand carts, and piled for curing in a place convenient for shipment. The lumber as it comes out of the sawmill is usually wet, green, rough, and cut to ordinary stock sizes only.

Defects. The defects that occur in lumber may be incidental to the growth of the tree or due to improper handling and sawing. *Sapwood* is soft, and usually it will shrink, warp, and crack in curing. The *pith* or center wood may be rotten, soft, and cracked. *Pitch pockets* are irregular openings filled with pitch which may occur anywhere and weaken the piece. *Ringshake* is a lack of bond between the annular rings which permits them to separate easily (Fig. 113). *Heartshake* is a series of radial cracks (Fig. 114). *Knots* are formed by limbs which start their growth near the center and may have been alive at the time the tree was cut or may have been dead and healed over by sapwood and bark. The saw may have cut across these knots, leaving an irregular defect circular in shape, or lengthwise, leaving a pyramidal-shaped defect called *spike knot* (Fig. 115). Well-formed knots that have been dead for some time become loose and fall out on curing. Green knots are usually tight and remain in place, but frequently exude pitch or sap. Knots greatly decrease the tensile and bending strength of a timber, but tight knots are not a serious defect in compression. The defects that occur in some woods which give it the name of *curly* or *bird's-eye* are due to buds that form each year in the sapwood and never develop. These are not truly defects, as they do not injure the timber and usually give it an increased value for ornamental purposes. *Worm holes* and *dry rot*

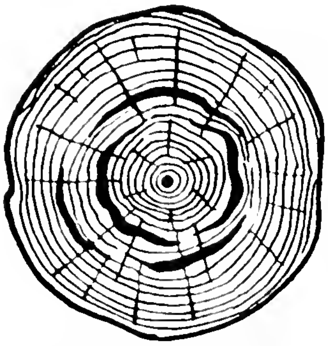


FIG. 113. *Ring or windshake*

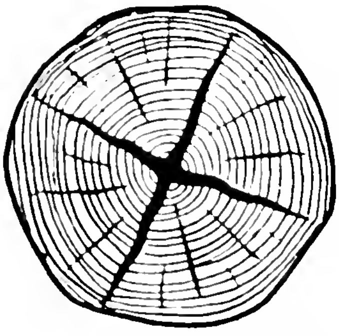


FIG. 114. *Heartshake*

are defects that may occur in the tree at the time it is cut or if the log is allowed to lie for a long period after cutting, and these defects may be developed to such a point that they render the log worthless for sawing. Faulty sawing may cause the stock to be thicker on one edge than on the other, or it may be across the grain. Defective logs are usually cut into dimension lumber and timber and used rough.

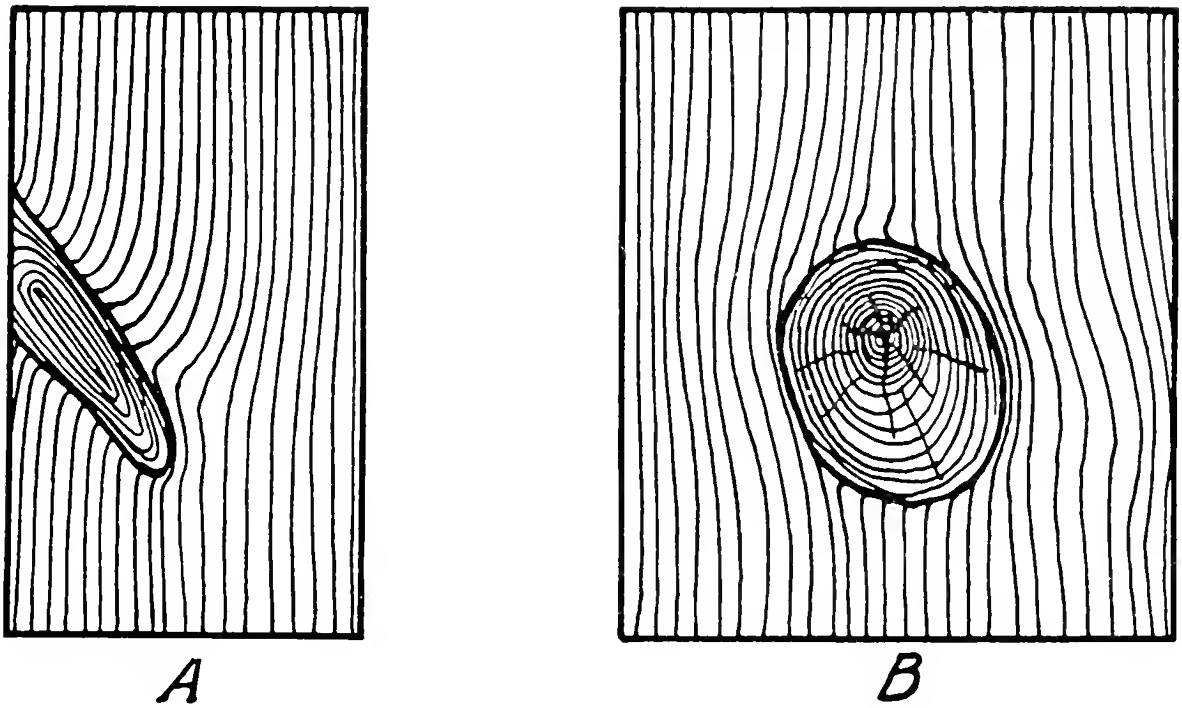


Fig. 115. *Knots*
A—Spike knot B—Circular knot

Finishing lumber and No. 1 lumber of the different grades must be reasonably free from the above-named defects, as a large part of it requires additional sawing or machine work to put it into final form for use. Material requiring paint, oil finish, or a smooth surface on one or more sides must have the saw marks and roughness taken off by the planing mill. Such lumber is known under the term *surfaced*. The manufacture of implements and the construction of modern buildings require special shapes and sizes that necessitate putting the sawed lumber through a machine to give it the desired form, after which it is known under a trade name.

Mill work. Mill work includes all lumber which has been worked or surfaced on more than two sides, such as window and door frames, outside casings, inside trimmings, baseboards, finished flooring, window sash, storm sash, screen doors, mantels, corner beads, picture rails, plate rails, and any special shapes which may be desired for cornice embellishment.

Curing. Curing of lumber, technically known as *drying*, has an important bearing on the preservation and life of the structure made from it. The tendency of all lumber is to shrink, warp, and crack as the moisture leaves it (Fig. 116). These drying defects vary in a greater or less degree with lumber made from different species of trees and in the same species, depending on the age of the tree and the part of the trunk from which the piece is taken.

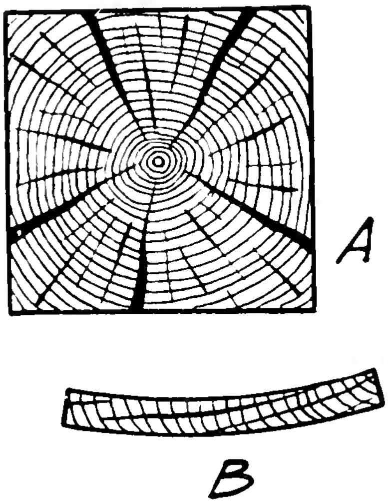


FIG. 116. *Effects of curing*
A—Shrinkage cracks
B—Warping

The defects initiated by drying on coming from the mill are exaggerated by exposure to the air, as the lumber gives off moisture on clear days and absorbs it on damp ones. The effect of drying on some wood is so marked as to render it worthless for the building of permanent structures that would be exposed to ordinary atmospheric conditions, owing to twisting, cracking, or its alternate expanding and contracting. The life of a piece of common wood may be extended indefinitely if it is always kept wet or perfectly dry; but if it is laid on the earth as it comes from the mill and exposed to ordinary atmospheric conditions, it will be rendered worthless in from six to ten years.

To minimize the deteriorating effects of drying, wood should be as thoroughly seasoned as possible before being used. The best method would be to have the log thoroughly dried before it is sawed, but from the commercial standpoint this is impracticable; the sawed lumber is therefore seasoned by being carefully piled so as to permit a free circulation of air around each piece. The pieces are laid flat and sufficiently supported to prevent sagging. The weight of the upper layers in the pile tends to prevent warping in the lower ones. For many purposes the piling process is too slow, and artificial drying is resorted to. Lumber is placed in rooms and heat applied, the required degree of curing being completed in a few days. Lumber thus cured is known as *kiln-dried* in distinction to *seasoned*, for which the curing is done in the air. The effect of exposure to the atmosphere on kiln-dried lumber is much more severe than on lumber seasoned in piles. Every effort should be made to protect lumber from moisture in the atmosphere after it is cured by having it placed in dry storage, treated with wood preservatives, and, after construction, by the use of fillers, oils, and paints.

Sizes. As the lumber leaves the saw its actual dimensions are the same as the nominal dimensions, any appreciable amount of undersize placing the piece in a lower grade. The nominal size as it comes from the mill is retained, although the actual size is decreased by shrinkage, surfacing, and additional machine work. The length is in even feet, and changes by 2 feet, as 10 feet, 12 feet, and 14 feet. Lengths shorter than 10 feet or longer than 24 feet are not regularly carried in stock, and the price usually increases for lengths above 16 feet. The width begins at 4 inches and increases by 2-inch gradations. Widths above 12 inches are not always carried in stock and command a higher price. The thickness may be ½ inch, 1 inch, 1¼ inches, 1½ inches, and 2 inches, after which it increases by 2-inch gradations up to the thickest piece carried in stock. The table at the top of page 116 gives the actual sizes of lumber after it has been surfaced on one side and one edge, although it is sold under the size which it had on coming from the saw.

SAWED WIDTH	2-INCH	4-INCH	6-INCH	8-INCH	10-INCH	12-INCH
SAWED DEPTH	Actual Width and Thickness of Lumber Surfaced on One Side and One Edge					
4″	1⅝ × 3⅝	3⅝ × 3⅝				
6″	1⅝ × 5⅝	3⅝ × 5⅝	5⅝ × 5⅝			
8″	1⅝ × 7½	3⅝ × 7⅝	5¾ × 7¾	7¾ × 7¾		
10″	1⅝ × 9½	3⅝ × 9⅝	5¾ × 9¾	7¾ × 9¾	9¾ × 9¾	
12″	1⅝ × 11½	3⅝ × 11⅝	5¾ × 11¾	7¾ × 11¾	9¾ × 11¾	11¾ × 11¾

The above timbers surfaced on four sides are reduced ½ inch in each dimension. A 1-inch rough board surfaced on two sides will be reduced in thickness to ¾ inch. Timber may be had up to 24 inches by 36 inches, surfaced on one side and one edge with a decrease of ¼ inch in each dimension after surfacing, or surfaced on four sides with a decrease of ½ inch in each dimension. Three-inch matched ceiling and flooring laid will cover only 50 per cent of the nominal area; 4-inch, 67 per cent; and 6-inch, 80 per cent; 1½-inch face flooring matched will cover only 50 per cent of the nominal area; 2-inch, 62½ per cent; 2¼-inch, 66⅔ per cent; and 3¼-inch, 76 per cent.

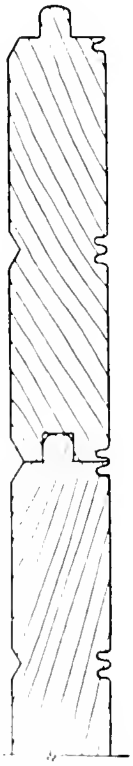


FIG. 117. V-groove beaded ceiling

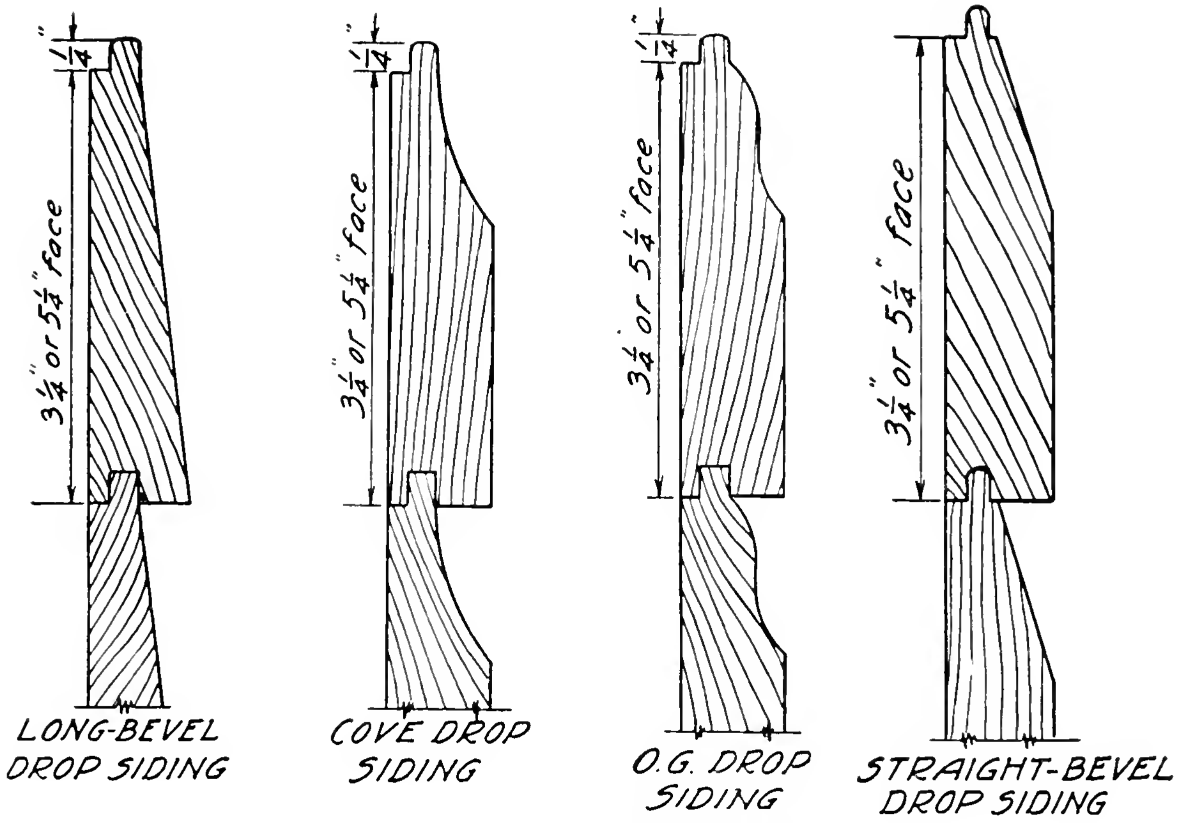
Definition of terms. Terms used in the grading and sale of lumber follow.

Ceiling. Lumber ⅜ inch, ⅝ inch, ¾ inch thick, surfaced on one side, with bead on tongued edge and at the center. When the back has a **V**-groove as shown in Figure 117, it is called *partition*. Ceiling commonly used comes in 4-inch and 6-inch widths.

Drop siding. Lumber which has been prepared for use as the outside covering of a building. It is dressed and matched and the face corner next to the tongue is shaped (Fig. 118).

D & M. Lumber which has been dressed and matched with a tongue and groove (Fig. 119).

Finishing. Lumber of such quality that it can be used for the outside or inside finish of a building, as the doors, casings, base, cornice, and barge board.



LONG-BEVEL DROP SIDING

COVE DROP SIDING

O.G. DROP SIDING

STRAIGHT-BEVEL DROP SIDING

FIG. 118. *Styles of drop siding*

Hardness. The term used to indicate the degree of resistance which a wood will offer to outside pressure without being dented. It is very hard when a pressure of 3,000 pounds per square inch will not make a dent over $\frac{1}{20}$ of an inch deep; hard when 2,500 pounds will produce this dent; fairly hard when 1,500 pounds will produce it, and soft when the same dent is produced by less than 1,500 pounds.

Lapsiding. Lumber in 4-inch and 6-inch widths, shaped as in Figure 120, page 118. Made by resawing a 1-inch board at an angle, thus forming two pieces of siding. (Sometimes known as beveled siding or clapboards.)

Milled shapes. Lumber with other than two pairs of parallel faces.

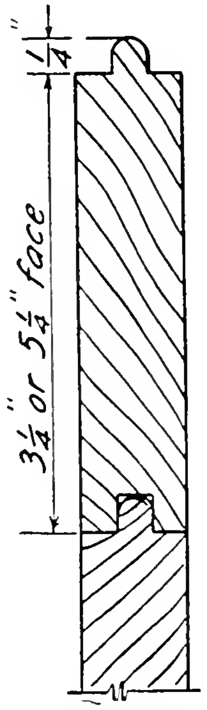


FIG. 119. *D & M lumber dressed and matched*

Rf. Lumber rough as it comes from the saw.

Rustic siding. Made of 1-inch lumber 8 or 10 inches wide with a shiplap joint and one or both faces machined to shape.

Shiplap. Lumber which has been prepared with a joint as in Figure 121.

S1S. Lumber surfaced on one side.

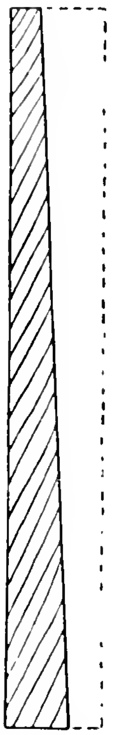


FIG. 120.
Lapsiding

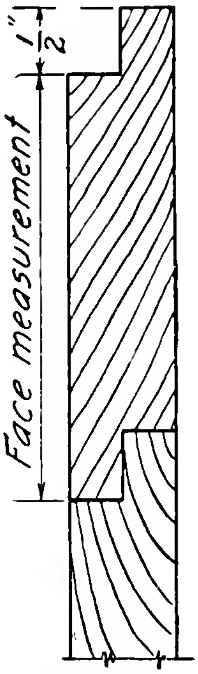


FIG. 121.
Shiplap

S1S1E. Lumber surfaced one side and one edge.

S2S1E. Lumber surfaced on two sides and one edge.

S4S. Lumber surfaced on four sides.

1S. One side.

Veneer. A thin sheet of an ornamental or long-wearing wood glued on the surface of a cheap wood. The veneer gives a finish and wearing surface and the other rigidity and strength.

Wane. A term applied to indicate a shortage of wood or the presence of bark on one edge of a timber.

Classification. All lumber ½" to 1½" in thickness is known as *board*. Sizes from 2"×4" to 4"×6" are known as *dimension* or *light timber*. Heavier than 4"×6" is usually known as *timber*.

Grades. Lumber is graded according to the species of the tree from which it is produced, the term usually indicating its quality, as hard or soft. It is also graded according to the purpose for which it is to be used, as flooring, siding, or fencing; dimensions to which cut, as boards, 1 inch by 8 inches by 12 feet, or 2 inches by 4 inches by 14 feet; and defects with respect to their bearing on the structure in which it is to be used, as C flooring, A clear siding, or No. 3 fencing. Each of these terms indicates a certain freedom from knots and other defects in the lumber named.

The system of grading is not uniform over the country, and its nomenclature is not completely standardized. The same name is not always given to the same species of tree, and the same nomenclature with respect to defects is not always analogous in the different species. A treatise on

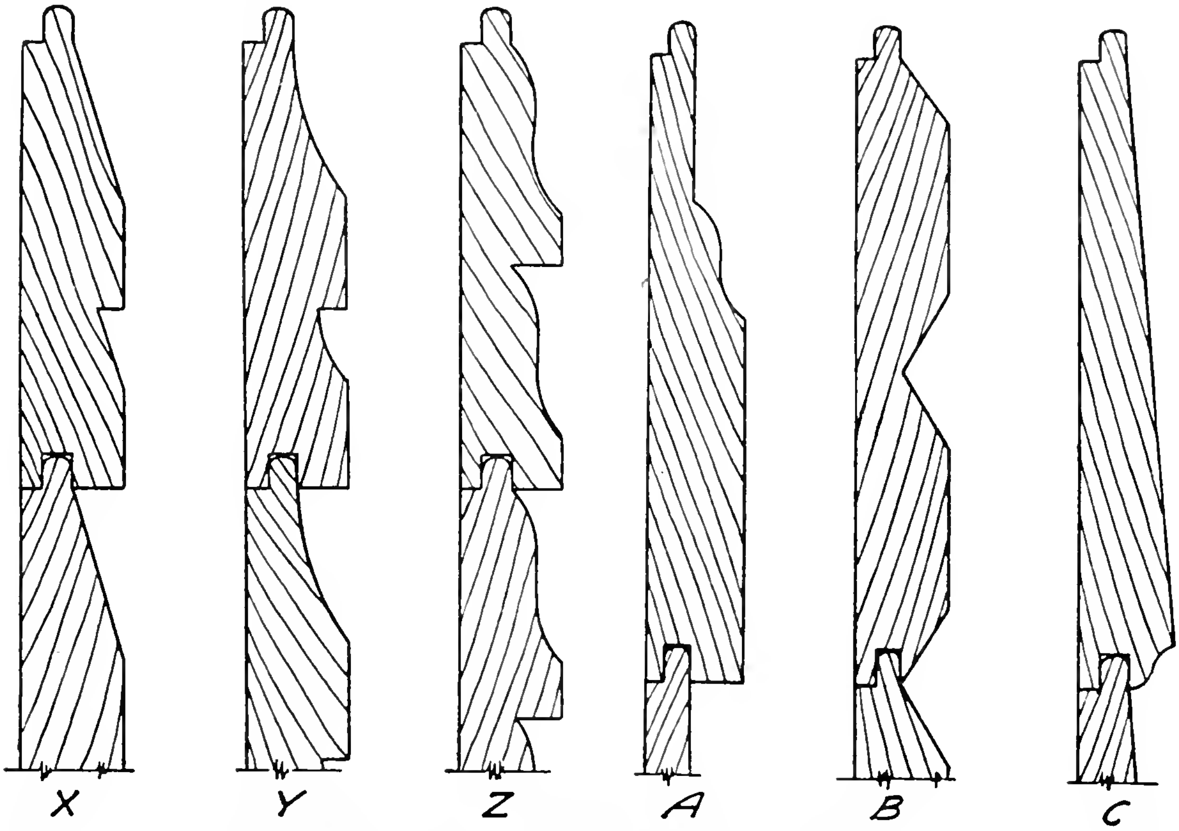


FIG. 122. *Special milled shapes, with matched stock used as a base. Catalog designation shown by letter.*

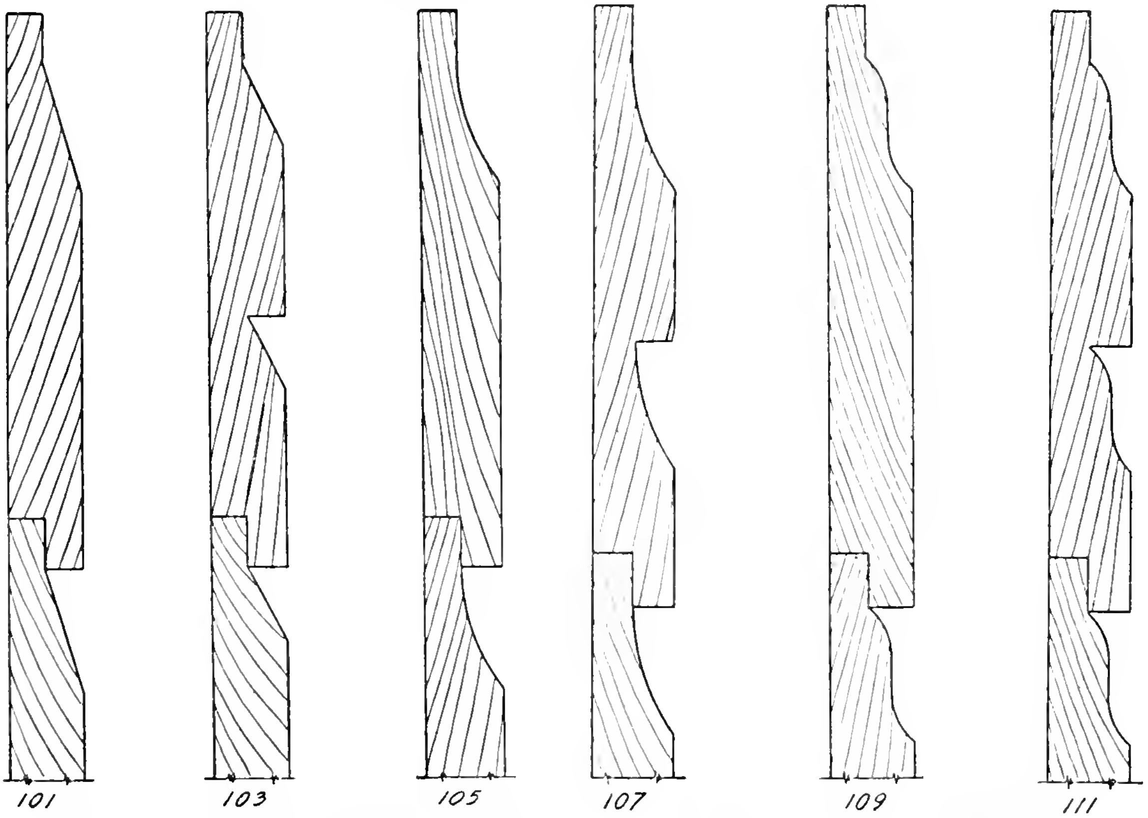


FIG. 123. *Rustic outside finish based on shiplap. Number indicates catalog designation.*

lumber grading which would include all the terms used and their meaning would require a small volume, and such knowledge is necessary only to the expert lumberman. For farm purposes lumber is usually bought at a local yard which will have in stock the kinds of lumber that can be most readily secured at the least cost and will answer the requirements of that locality. The following are standard grades of white pine, Norway pine, spruce, and tamarack, for which there is the most call at the smaller lumber yards and which are carried in stock:

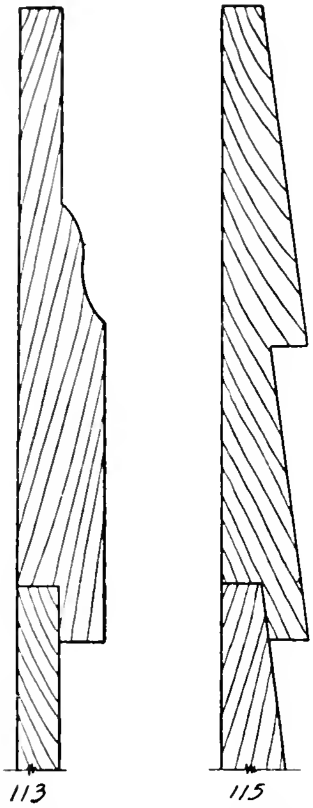


FIG. 124. *Special rustic shapes. Number indicates catalog designation.*

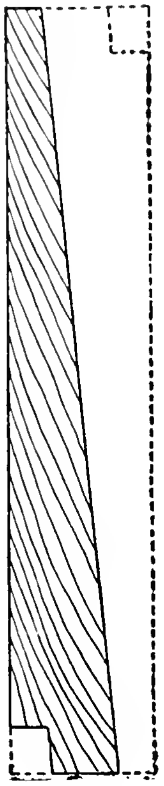


FIG. 125. *Thick rustic bevel siding resawed from 2″ stock*

Ceilings:

White Pine, Norway, Yellow Pine

4″ V-Grooved 1S Single or Double-Beaded 1S
6″ V-Grooved 1S Single or Double-Beaded 1S

Common Boards:

No. 1 and No. 2 Stock Widths
No. 3, No. 4, and No. 5 Mixed Widths

These may be had rough, surfaced on one side, or surfaced on two sides. The No. 1 common boards can be used for outside finish where it is to be painted. The general practice is to order No. 4 boards and pick out the best for sheathing, taking the poorest for first or rough floors. This cannot always be done, as a great many of the country yards do not handle grades lower than No. 2.

Dimension:

No. 1 and No. 2

Fencing:

4″ No. 3; 6″ No. 3; and 6″ No. 4

These may be had rough or dressed and matched, when they are sometimes used for flooring. They are made surfaced on two sides or $\frac{3}{4}''$ in thickness, with $5\frac{1}{4}''$ face for the 6″ stock, and $3\frac{1}{4}''$ face for the 4″ stock. The detail section is shown in Figure 119.

Finishing:

B and Better White Pine
C White Pine
D White Pine
C and Better Norway Pine

These come in variable widths of even inches. The white-pine finish mentioned above is generally used for outside finish, while the Norway pine is used for inside finish. Very little finish of the above grade would be used outside where the entire surface is to be painted. Only when the outside is to be stained is it necessary to use the higher-grade material.

Lath:

No. 1 and No. 2; 48″ and 32″ length

Lapsiding:

4″ C White Pine
6″ C White Pine
4″ D White Pine
6″ D White Pine

Rustic Siding:

10″ Norway Pine
8″ White Pine

Shiplap and Sidings:

No. 2 Drop siding $3\frac{1}{4}''$ or $5\frac{1}{4}''$ face (Fig. 118)
6″ No. 2 Straight beveled siding
6″ No. 1 Cove drop siding
6″ No. 1 O. G. Drop siding
8″ No. 3 Shiplap
10″ No. 4 Shiplap

HARDWOOD LUMBER CARRIED IN STOCK

Oak:

Rough Wagon Stock:
  2″×3″×4′ to 4″×12″×20′
No. 1 Common:
  2″×4″×6′ to 4″×6″×20′

- No. 1 Common White Oak:
  - 6″×6″×8′ to 12″×12″×28′
- Plain sawed Red and White Oak, 1st and 2d Clear:
  - ½″; ⅝″; 1¼; 1½″; 2″; 2½″; and 3″ thickness
  - 6″ and wider
  - Mixed lengths
- No. 1 and No. 2 Common Red and White:
  - 1″; 1¼″; 1½″; 2″; 2½″; 3″, and 4″ thickness
  - Mixed widths and lengths
- Quarter-sawed Red and White, 1st and 2d Clear:
  - ½″; ⅝″; 1″; 1¼″; 1½″; and 2″ thickness
  - Mixed widths and lengths
- Bridge Plank, Rough:
  - 2″×6″ and 3″×6″
  - 8′ to 16′ length

Elm:

- Bridge Plank, Rough:
  - Dimensions same as Oak bridge plank
- Machine Stock (sizes used for implements)

Maple:

- 1st and 2d Clear:
  - 1″; 1¼″; 1½″; 2″; 2½″; 3″, and 4″ thickness
  - Market lengths and widths
- No. 1 Common and No. 2 Common:
  - Same sizes as 1st and 2d Clear

Birch:

- 1st and 2d Clear:
  - ½″; ⅝″; 1″; 1¼″; 2″; 2½″, and 3″ thickness
  - Market widths and lengths
- No. 1 Common:
  - 1″; 1¼″; 1½″, and 2″ thickness
  - Market widths and lengths

Basswood:

- Clear Siding:
  - 1″×4″, 5″, and 6″; 4′ to 16′ lengths
- Base:
  - Standard widths
- Casings:
  - Standard widths
- Ceiling:
  - ⅜″×¾″; 4′ to 16′ lengths
- Finish 1st and 2d Clear S2S:
  - ⅜″; ½″; ⅝″; 1″ thickness ×12″ width

Poplar:
  1st and 2d Clear:
    ½″; ⅝″; 1″; 1¼:″ 1½″; 2″×6″, and up
    Random widths and lengths
Brown Ash:
  1st and 2d Clear and No. 1 Common:
    1″; 1¼″; 1½″; 2″ thickness
Hickory:
  1st and 2d Clear:
    1″; 1¼″; 1½″; 2″; 3″, and 4″ thickness

Qualities of conifers. *Cedar.* There are five varieties of white cedar and two varieties of red, one of which is the redwood of California. The white cedar is a grayish-brown color and the red a brownish-red. They are light, soft, of fine texture, do not shrink or check, and are very durable. They are used for shingles, posts, and railroad ties. The redwood is used for exterior finish.

Cypress. Cypress is light, soft, straight-grained, and has great resistance to the effect of moisture and warping. It is used for shingles, siding, water tables, sills, and gutters.

Hemlock. There are two varieties, light reddish-gray in color, light, and soft. They shrink and check badly and are rough, brittle, and cross-grained. Hemlock is used for sheeting.

Spruce. There are three species. They are whitish in color, light, soft, and fairly strong. Spruce is used for light framing and sheeting.

Pine. Two varieties produce softwood lumber, and five, hardwood lumber. Four varieties of the hard pine grow in the South and are frequently referred to as southern pine. The hard pine of the North is known as Norway pine. Each species of pine is known in various parts of the country under a different local name. The pine is strong, straight-grained, shrinks and cracks moderately in drying, and is used for nearly all construction purposes.

Tamarack. Tamarack is yellow-white in color, heavy, warps and cracks, and is used for light framing and sheeting.

Fir. Fir is yellow and red in color, light, straight-grained, warps and cracks, and is used in framing and sheeting.

Qualities of broad-leaved trees. *Ash.* There are two species. They are light in color, heavy, hard, shrink moderately, take a good polish, and are used for inside finish.

Beech. The color is from white to brown. Beech is heavy, hard, strong, of coarse texture, shrinks and checks, and is not durable when placed on the ground. It takes a good polish and is used for inside finish.

Birch. Birch is white and red in color, heavy, medium hard, does not warp, is not durable when exposed, and takes a good polish. It is used for inside finish, floors, and an imitation of cherry and mahogany.

Chestnut. The wood is light brown in color, light, fairly soft, not strong, coarse in texture, shrinks and checks, and is very durable. It is used in interior finish and cabinet work; also for cross arms on pole lines.

Hickory. Hickory is white in color, very heavy, hard and tough, straight-grained. It cannot be nailed. It is used for handles, wheels of vehicles, and parts of implements. The second growth is tougher than the original.

Elm. There are five species. The color varies from brown to shades of gray and red. Elm is heavy, hard, tough, cross-grained, shrinks and checks badly in drying, and takes a high polish and a good stain. It is used in the manufacture of implements.

Gum. Gum is reddish brown in color, heavy, soft, strong, of a fine texture, and warps and checks badly if exposed. It is used for interior finish, furniture, and cabinet work.

Maple. Maple comes from the tree known as sugar maple. It has creamy-white color, is heavy, strong, of fine texture, shrinks moderately, and takes a good polish. It is used for flooring, inside finish, and furniture.

Oak. There are twenty different varieties, ten of which are marketed as white oak and ten as red oak. White oak

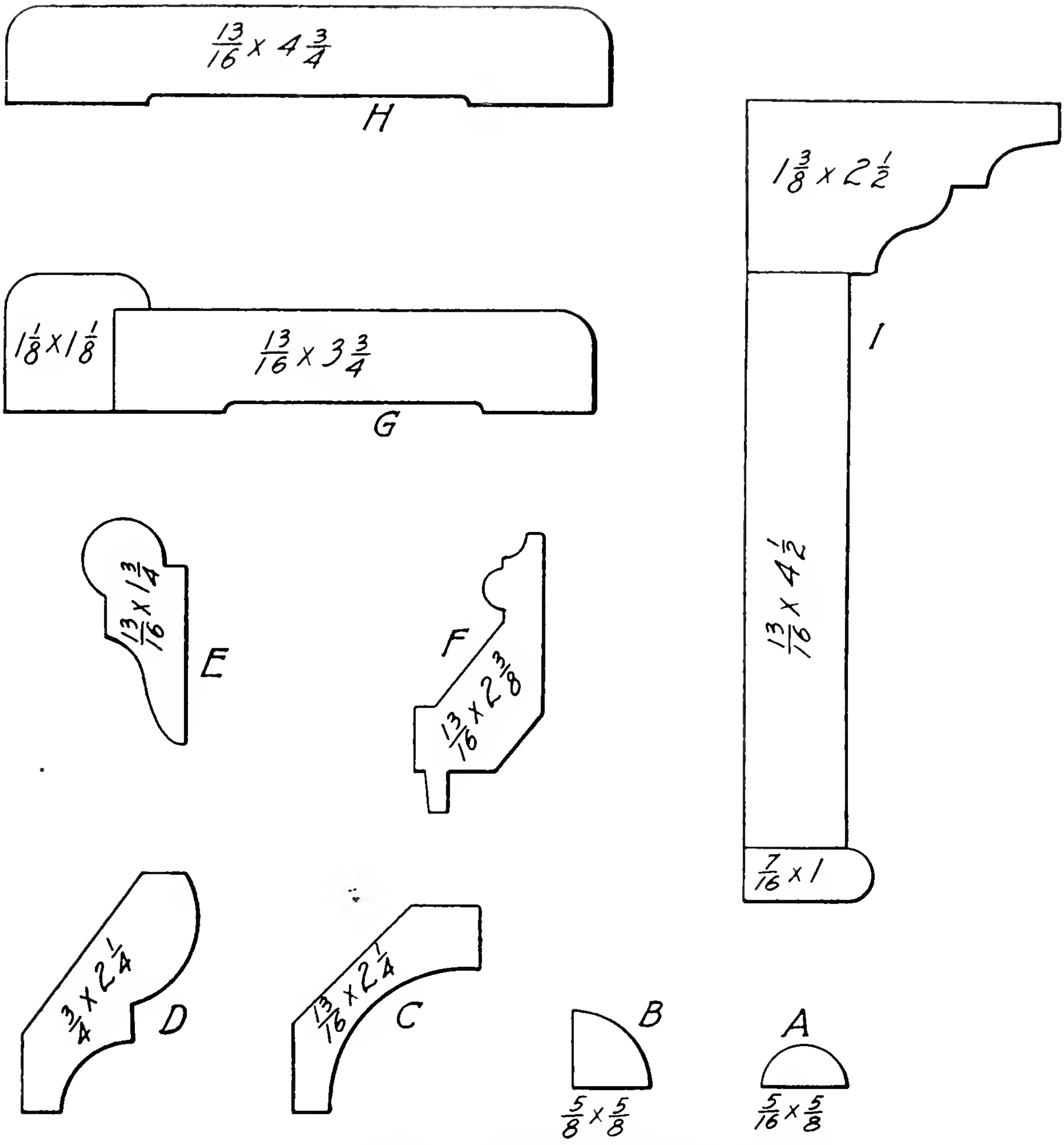


FIG. 126. *Standard forms used in interior finish*

A—½ round
B—¼ round
C—Sprung mold
D—Crown mold
E—Picture mold
F—Base mold
G—Casing with backing
H—Plain casing
I—Three-member header finish, using fillet and cap

has a straw color; red oak has a reddish tinge and is less durable than the white oak. Both are heavy, hard, of coarse texture, shrink, and crack. They are used for inside finish and furniture. The ornamental and wearing qualities are improved by quarter-sawing.

Poplar. Poplar is also known as white or tulip wood, there being a number of different varieties, white or yellow-white in color, light, soft, free from knots, and of fine texture. Poplar warps badly. It is often stained to imitate more costly woods, and is used for table tops and pumps.

Sycamore. Sycamore is yellowish in color, heavy, hard, strong, of coarse texture, cross-grained, hard to work, and it shrinks, warps, and checks badly. It is used for meat blocks in butcher shops.

Walnut. Walnut is very dark brown in color, heavy, hard, of coarse texture, shrinks moderately, and takes a beautiful polish. It is used for interior finish and furniture. Butternut, a species of walnut, is light brown in color, light, soft, and weak.

Suitability. The purposes for which various woods are suitable are as follows:

Heavy framing: Washington or Douglas fir, yellow pine, swamp oak
Light framing: Fir, white pine, hemlock, tamarack, spruce
Sheeting: White pine, tamarack, hemlock, spruce, fir
Exterior finish: White pine, redwood, cypress, poplar
Interior finish: Fir, yellow pine, all hard woods
Flooring: Quarter-sawed oak, birch, yellow pine, maple, fir
Doors and sash: White pine, yellow pine, cypress, redwood
Doors (veneered): White pine, redwood
Linen closets: Western white cedar, southern red cedar
Posts: White cedar, redwood, cypress, locust

Weight. The weight of lumber varies greatly according to the quantity of moisture contained. Thoroughly cured lumber is much lighter than wet or green lumber. The following table gives the approximate weight per cubic foot of fairly dry lumber:

	Pounds per Cubic Foot		Pounds per Cubic Foot
Ash	40	Hickory	48
Birch	40	Maple	43
Cedar	25	Oak	48
Chestnut	30	Pine, Norway	34
Cypress	28	Pine, white	27
Elm	44	Pine, yellow	42
Fir	30	Spruce	28
Gum	37	Tamarack	39
Hemlock	28	Walnut	37

To find the weight of a board foot of the foregoing woods, divide the weight given by 12.

Measurement for sale. Lumber is sold by the *board foot*, which is 1 square foot in area and 1 inch in thickness. Example: A board 1 inch thick, 10 inches wide, and 12 feet long would contain 10 board feet. The same board 2 inches thick would contain 20 board feet. The number of board feet in lumber less than 1 inch in thickness is figured the same as though it were 1 inch thick. A board ½ inch thick, 10 inches wide, and 12 feet long would be counted as 10 board feet. The price on lumber is quoted at so much per thousand board feet, excepting special forms and small sizes put up in bundles, which are quoted by the lineal foot or by the bundle. In a lumber order, when all dimensions are given, the number of pieces should be stated; when mixed widths and lengths can be used, the number of board feet should be specified.

EXAMPLE OF A LUMBER ORDER

12 pc.	2″×4″×14′ No. 3 Rf. White Pine
6 pc.	2″×4″×12′ No. 1 S1S1E White Pine
4 pc.	2″×4″×10′ No. 1 S4S White Pine
10 pc.	Finishing 1¼″×10″×12′. 1st Clear B Select. White Pine
400 ft.	1″ Finishing. 1st Clear A Select. White Pine
800 ft.	Bev. Siding. D Clear. Cypress
200 ft.	A Flooring
1000 ft.	Common Boards No. 4
200 ft.	6″ Fencing D & M No. 1
200 ft.	10″ Rustic Siding Norway

Conservation of lumber. The rapidity with which forest areas are being reduced by lumber operations, the slowness with which lumber-producing trees grow, and the resulting advance in lumber prices have led to the using of parts of trees and the cutting and sawing of species of trees that at one time were not considered as suitable for lumber, such material being used for barrels, boxes, and temporary construction where it is covered and well protected. To prevent further depletion of the forest areas, special efforts are made by national and state agencies to have lumber companies utilize all of the timber-producing trees cut, protect growing trees, leave at frequent intervals seed-producing trees, and clean up the brush in order that forest fires may not destroy the young growth.

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CHAPTER VIII[1]

CONCRETE

Concrete. Concrete is an artificial stone made by the mixture of cement, aggregate, and water. Its use in all lines of construction requires that some knowledge of this material, with the methods of using it, should be understood by everyone. Improper selection or use of materials and improper curing may result in poor construction or rapid deterioration.

TERMS AND DEFINITIONS

The following terms frequently occur in literature on cement, and their meaning should be clearly understood:

Bank-run gravel. Gravel mixed with sand as found in the natural bank.

Bond. The force with which concrete grips or holds to any foreign material.

Batch. The quantity of concrete mixed at one operation.

Cement matrix. That part of concrete formed by the cement and water.

Cement mortar. Cement mortar is a mixture of cement, sand, and water.

Consistency. The relative quantity of water held by the concrete.

Initial set. The first hardening of the cement mixture, usually taking place about thirty minutes after water is added.

Lean mixture. One containing a comparatively small quantity of cement.

Neat cement. Neat cement is a paste made by the mixture of cement and water without any other material.

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[1] After E. C. Crane, *University of Minnesota, General Series Bulletin No. 52.*

Rich mixture. One containing a comparatively large quantity of cement.

Voids. In a pile of sand, gravel, or rock there are always large open or air spaces between the grains or individual pieces. These open spaces in aggregate are known as *voids.* The percentage of voids is the proportion of the whole volume of the aggregate occupied by air or moisture.

CEMENT

Cement. Cement was used by the earliest civilizations, but during the Middle Ages it was replaced by lime mortar. In the eighteenth century cement again came into use in England.

Cement is a fine powder which possesses the property of hardening after being mixed with water. In this hardening process it will bind together, when properly mixed with them, particles of sand and stone into one solid mass. This is the property which makes it so useful for construction.

The properties essential in cement-making material are a calcareous element combined with an argillaceous element. The first is usually contained in limestone and the latter in clay or blast furnace slag. In addition to these two general elements there are small quantities of iron, sulphur, and manganese compounds.

Natural cement. Natural cement is made by the process of burning a rock which contains all of the essential elements required in cement and then grinding this burned material to a fine powder. Since the quantities of the necessary elements for cement making vary considerably in the natural rock, the best results are not obtained from this process. However, natural cement is usually cheaper than other kinds, and it is used where a large mass is required rather than great strength. Dams, retaining walls, and abutments are frequently built with this kind of cement.

Portland cement. Portland cement derives its name from the fact that where cement was first used in England, construction work made with it resembled a rock quarried at Portland. It differs from the other kinds in that the two materials necessary for cement making are obtained in different places, carefully selected, ground, and mixed, then burned and reground. As a result of this special selection and mixing, Portland cement is best for general purposes, as its action and strength are more uniform than those of any of the other varieties. It has about three times the tensile strength of ordinary natural cement.

Manufacture and handling of cement. A cement-manufacturing plant is a large institution, requiring an expensive investment in machinery for handling the raw material, crushing, grinding, conveying, and large rotary burning kilns. Provision is made for carefully sampling the materials and for mixing them at the proper time and in the proper proportions. The product is manufactured in all plants in conformity to standard specifications.

Cement was formerly packed for shipment in barrels, and the term barrel became so common that it is still considered the standard unit for measuring, although at the present time practically all cement is packed and shipped in sacks. One sack of cement weighs 94 pounds net. Four sacks of Portland cement or three sacks of natural cement make a barrel. For practical purposes, one sack of Portland cement may be considered as 1 cubic foot.

Cement in small quantities, if purchased from reliable dealers, is satisfactory as a rule. If cement is stored, it should be placed where it cannot get wet from above, and particular attention should be given to placing planks or other dry material under the sacks. Wet cement immediately begins to harden and will never set properly even though it has been repulverized.

AGGREGATE

Aggregate. *Aggregate* is mineral material, such as sand, gravel, crushed rock, and rock screenings, and consists of both fine and coarse material. All of this material which will pass through a screen with quarter-inch openings is known as fine aggregate, and that which remains on the quarter-inch screen is known as coarse aggregate.

To construct good concrete, the selection of good aggregate is as important as the selection of good cement. A satisfactory aggregate must be strong, and the individual grains or pieces must be so free from dirt that the wet cement can adhere to each. The size of the aggregate should be such that, when thoroughly mixed, the smaller particles fill in between the larger and reduce the voids to a minimum.

Coarse aggregate. Coarse aggregate should be hard, strong stone, such that the strength of the concrete will not be limited by the strength of the stone. Gravel, limestone, granite, trap-rock, and the harder sandstones are used. Soft, rotten rock which easily splits, scales, or breaks should be avoided, as it is weaker than the cement matrix. In fireproof construction where strength is not necessary cinders are used. Crushed rock or gravel used as coarse aggregate should be clean and graded in size from the largest to the smallest, so that the percentage of voids will be at a minimum, the same as in fine aggregate. The limit of maximum size of coarse aggregate depends upon where the concrete is to be used. In heavy walls the maximum size may be as much as 3 inches in the largest diameter and 1 inch for thin sections and reinforced work. Where large mass is required, rubble concrete is used, in which the maximum diameter of stones may be 5 or 6 inches.

Fine aggregate. Fine aggregate, which is sand or screenings from crushed rock, should be hard grains, free from loam, clay, vegetable matter, or dirt of any character. The word "sharp" in the description of fine aggregate means that the material, when rubbed in the hands, gives a sharp feeling on account of containing the proper proportion of various-sized, clean grains. The term should not be understood to mean grains that are angular with sharp corners, for many good sands are composed of spherical grains. In the examination of a sand bank an idea of the quality of the sand to be used as fine aggregate may be had by means of samples of the sand rubbed between the palms. Good sand will feel sharp, as described above, and will not leave a great quantity of dirt on the hands. If a more complete test is desired, it may be secured by means of filling a straight-sided glass vessel from one-third to one-half full of sand; adding enough water to cover the sand from 2 to 4 inches; shaking thoroughly, and then letting the vessel stand until the sand has settled. The clean sand will be on the bottom and the dirt on top. By measurement of the depth of the sand and of the worthless material, the percentage of dirt may be obtained. Sand containing 3 or 4 per cent of dirt is very clean; 10 to 12 per cent dirt may be used without affecting the strength of the concrete seriously.

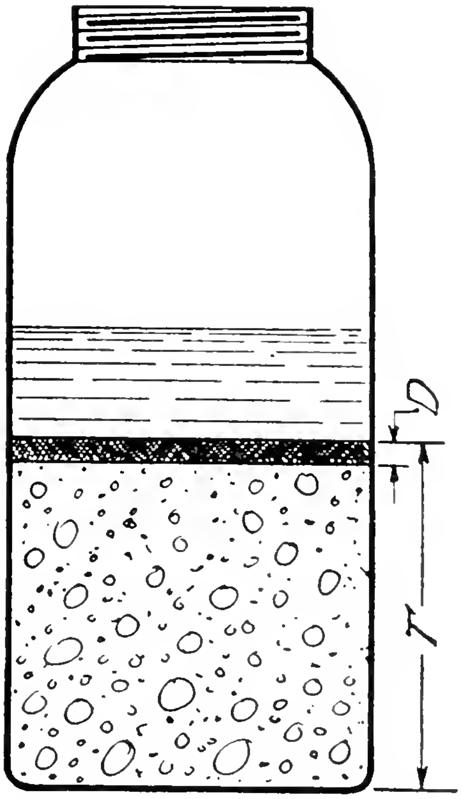

FIG. 127. *Method of testing dirty sand*

$\frac{D}{T}\times 100$ = per cent of dirt

D = thickness of dirt layer

T = total height of dirt and clean aggregate

If screenings are used for fine aggregate, they should be from good hard stone and clean. If sand is used in cement mortar, it must be screened to be separated from the coarser material, as mortar requires a fairly fine aggregate.

For obtaining the best results in concrete, the percentage of voids should be as small as possible. This is secured by use of an aggregate ranging from coarse to very fine grains, so that the finer grains fill in between the larger ones, and the still finer fill in between the medium grains. This gives

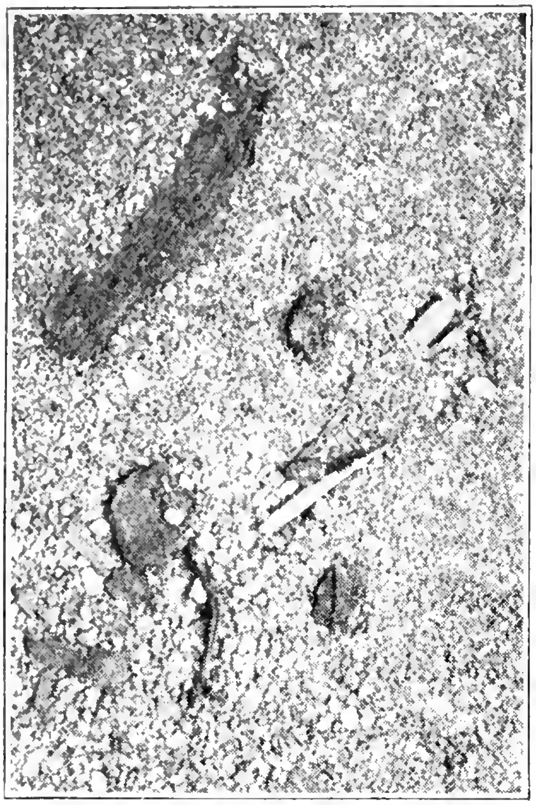

FIG. 128. *Sand containing foreign matter*

FIG. 129. *Very fine sand*

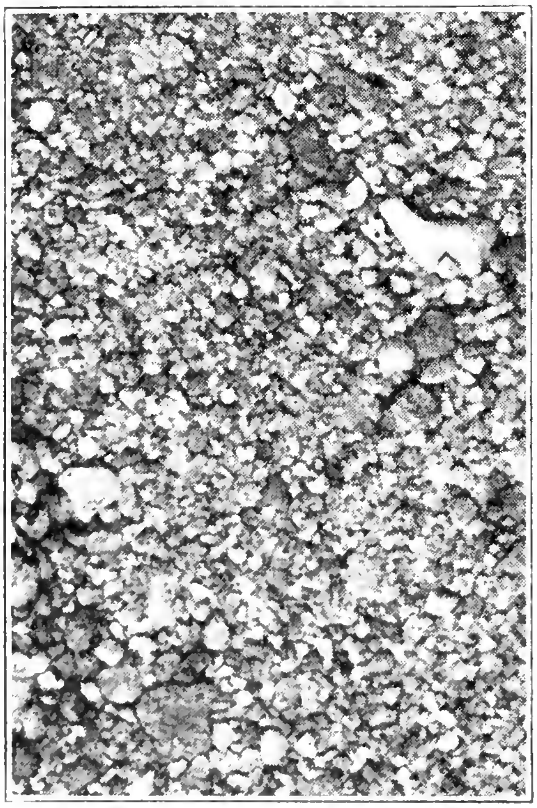

FIG. 130. *Clean, well-graded sand*

FIG. 131. *Limestone screenings that may be used in concrete work in place of sand*

a lower percentage of voids than an aggregate which consists of grains of uniform size. A sand of coarse grains is preferable to one of fine grains because, as a rule, the coarse sand contains some fine grains which mix in between the coarser ones. This makes a more compact mass, and it takes less cement to make a mortar of the same strength. With the same percentage of voids a coarser sand requires less cement for a given strength for the reason that there is less total surface of grains to be covered with cement.

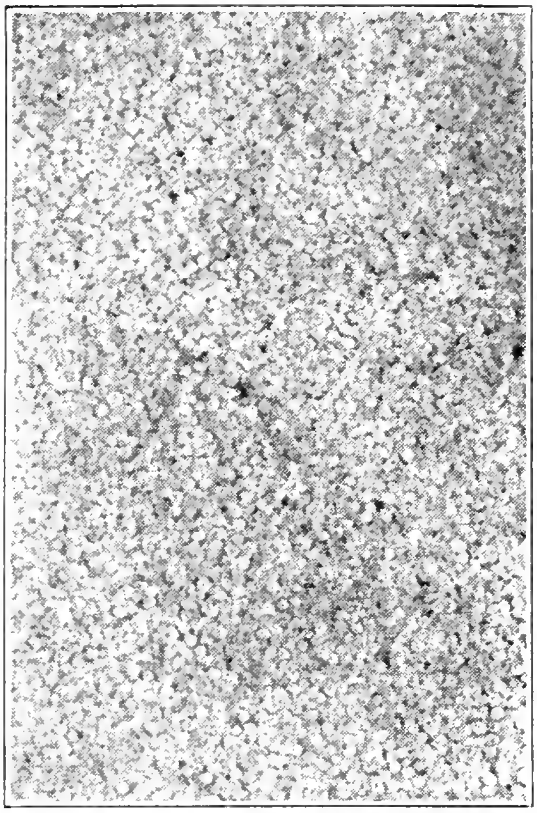
FIG. 132. *Standard Ottawa sand*

Standard sand. A clean, white, spherical-grained sand found in the vicinity of Ottawa, Illinois, is used throughout the United States as the standard sand for making comparative tests in concrete work. (Fig. 132.)


FIG. 133. *Concretion that is frequently found in gravel too weak for use in concrete*

Bank-run gravel. Gravel, as ordinarily found in the bank, does not contain the proper proportions for making the best concrete. However, in practice the gravel is generally used as found, though much more satisfactory results can be secured if the materials are screened as they come from the bank and then remixed in the proper proportions. The natural mixture of bank-run gravel may be determined by screening of a cubic foot or a cubic yard and measurement of the quantities which pass through the screen. Gravel seldom occurs uniform in the bank; coarse layers alternate with fine, while other strata may be intermixed with silt and clay. The user of bank-run gravel should be on the alert to detect any change in grading that will affect the quality of the concrete. Much poor concrete construction can be traced to natural mixed gravel.

MIXTURE

Ideal concrete. In ideal concrete all of the materials are graded and proportioned in size from the smallest to the largest so that the voids are practically zero, and sufficient cement is added to coat all of the individual particles. The result is a mass similar to solid rock. It is not practical to obtain the ideal. Where large quantities of concrete are being used, it is possible, by a series of tests, to secure more satisfactory results along this line than in smaller work. The small user of cement will have to depend, in mixing his materials for various purposes, upon formulas which are accepted by custom as being satisfactory for each purpose.

Designation by volume. The mixture of cement, fine, and coarse gravel is defined by numbers which represent volume of each material used. A 1 : 2 : 4 mixture means that one part, by volume, of cement has been mixed with two parts of sand or screenings and four parts of gravel or crushed rock. This may be measured in any convenient way, by half cubic feet, by cubic feet, or by the cubic yard. If the basis is 1 cubic foot of cement, it takes 2 cubic feet of sand and 4 cubic feet of gravel to go with it; or if the basis is ½ cubic foot of cement, it takes 1 cubic foot of sand and 2 cubic feet of gravel to go with it. Either of these gives a 1:2:4 mixture, but a batch of different size in each case. A common error is to think that this combination of one unit of cement, two units of sand, and four units of gravel will give a mixture 1+2+4=7 units in volume. It will not, when mixed, give seven units in volume as a result, because the cement fills in the voids in the sand, and the sand plus the cement fills in the voids in the gravel, thus combining to give, when all mixed together, but very little more than four units of gravel (perhaps 15 per cent more). Figure 134 illustrates this point.

Another common error is to consider a so-called 1:6 mixture, meaning a combination of one unit (by volume) of cement with six units of bank-run gravel, as giving the same result as this 1:2:4 mixture. It is evident that we obtain a weaker mixture in the 1:6 combination than in the 1:2:4, because in the finished product we have one unit of cement mixed with six units of aggregate in the first case as against one unit of cement mixed with about four units of aggregate in the second case.

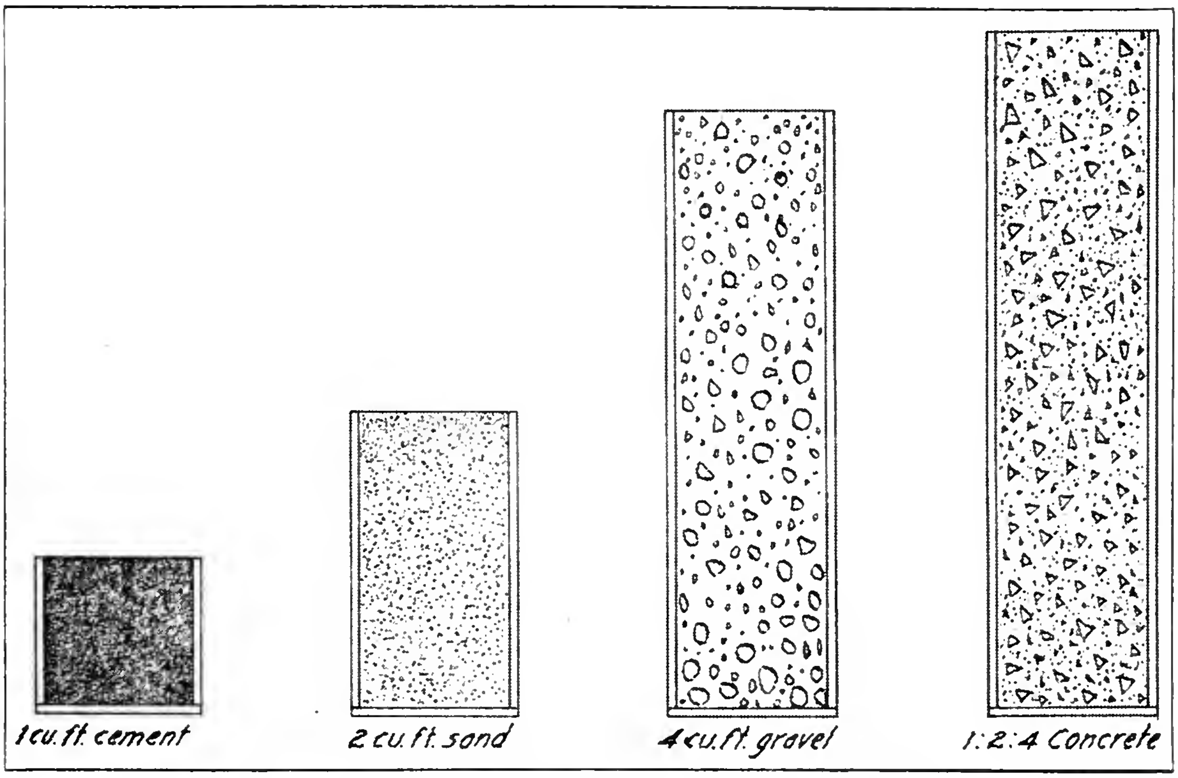

FIG. 134. *Diagram showing total volume made by combining 1 part cement, 2 parts fine aggregate, and 4 parts coarse aggregate*

VOLUME OF CONCRETE FROM 4 SACKS OF CEMENT — 3.8 CUBIC FEET

Proportions by Volume			Quantities	
Cement	Sand	Stone	Cu. Ft.	Cu. Yd.
1	1	2	10.0	.37
1	2	4	17.3	.64
1	2½	5	20.8	.77
1	3	6	24.3	.90
1	4	8	31.7	1.17

VOLUME OF MORTAR FROM 4 SACKS OF CEMENT — 3.8 CUBIC FEET

Proportion by Volume		Quantities	
Cement	Sand	Cu. Ft.	Cu. Yd.
1	1	5.4	.20
1	2	8.1	.30
1	3	10.8	.40
1	4	13.5	.50
1	5	16.2	.60
1	6	18.9	.70

TABLE OF MIXTURES

1 : 1 : 2½ or 1 : 1½ : 3	Small work requiring strength and impermeability
1 : 2 : 3 or 1 : 2 : 4	One-course floors, walks, barnyards, pavements, roofs, fence posts, sills and lintels without mortar surface, water troughs and tanks, and large machinery foundations
1 : 2½ : 4 or 1 : 2½ : 5	Building walls above foundations, silo walls, base of two-course sidewalks and pavement blocks
1 : 3 : 5 or 1 : 3 : 6	Basement walls and foundations, small machinery foundations, base of sidewalks and two-course floors, mass footings
1 : 4 : 8	Large masses, not much strength
1 : 1½	Wearing course of two-course floors
1 : 2	Scratch coat of exterior plaster, masonry mortar, wearing course of two-course walks, street pavements, barnyard pavements

1 : 2½	Finish coat of exterior plaster, fence posts when coarse aggregate is not used
1 : 3	Masonry mortar, cement-drain tile when coarse aggregate is not used, cement blocks

THICKNESS AND MIXTURE OF CONCRETE FOR TWO-COURSE WORK

Purpose	Depth of Base	Mix for Base	Thickness of Surface	Mix for Surface
Residence basement floors	3	1 : 2½ : 5	1 in.	1 : 2
Poultry-house floors	3½	1 : 3 : 6	½ in.	1 : 3
Hog-house floors	3	1 : 3 : 6	¾ in.	1 : 2
Cow-barn floors	4	1 : 3 : 6	¾ in.	1 : 2
Horse-barn floors	5	1 : 2½ : 5	1 in.	1 : 2
Sidewalks				
Base	4¼	1 : 2½ : 4		
Finish coat			¾ in.	1 : 2

THICKNESS AND MIXTURE OF CONCRETE FOR ONE-COURSE WORK

Purpose	Depth	Mix
Residence basement floors	4	1 : 2 : 4
Poultry-house floors	3	1 : 2 : 4
Hog-house floors	3½	1 : 2 : 4
Cow-barn floors	4½	1 : 2 : 4
Horse-barn floors	5½	1 : 2 : 3
Sidewalk	4½	1 : 2 : 3
Scratch coat	½	1 : 2
Finish coat	½	1 : 2½

QUANTITIES OF MATERIAL FOR 1 CUBIC YARD OF CONCRETE

PROPORTIONS BY VOLUME			QUANTITIES OF MATERIAL		
Cement	Sand	Stone	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.
1	1	2½	9.9	0.36	0.88
1	1½	3	8.0	.42	.85
1	2	3	7.4	.52	.78
1	2	4	6.4	.44	.90
1	2½	4	5.9	.52	.83
1	2½	5	5.2	.46	.91
1	3	5	4.9	.52	.86
1	3	6	4.4	.46	.94
1	4	8	3.4	.48	.96

QUANTITIES OF MATERIAL FOR 1 CUBIC YARD OF CEMENT MORTAR

Proportions by Volumes		Quantities of Material	
Cement	Sand	Cement Sacks	Sand Cu. Yd.
Neat cement		30.0	0.00
1	1	19.4	.70
1	1½	15.4	.82
1	2	12.8	.90
1	2½	10.8	.96
1	3	9.4	1.00
1	5	6.1	1.08

Lime. In the mixing of cement mortar, 5 to 10 per cent of thoroughly slacked lime may be added without injury. The addition of the lime makes the mortar more impervious to water and smoother to handle.

MIXING

Measuring. Some method of measuring exact volumes should be provided. Since the cement is in sacks, it is customary to have the measuring box of such size that it is proportionate to the sack of cement, a given number of boxes of coarse and fine aggregate being used for each sack of cement. By this method the measuring of cement is avoided.

Hand mixing. Hand mixing is the only method available for individual work. A mixing platform such as shown in Figure 136 is useful. The method of procedure to mix a one-bag batch of 1 : 2 : 4 mixture is as follows:

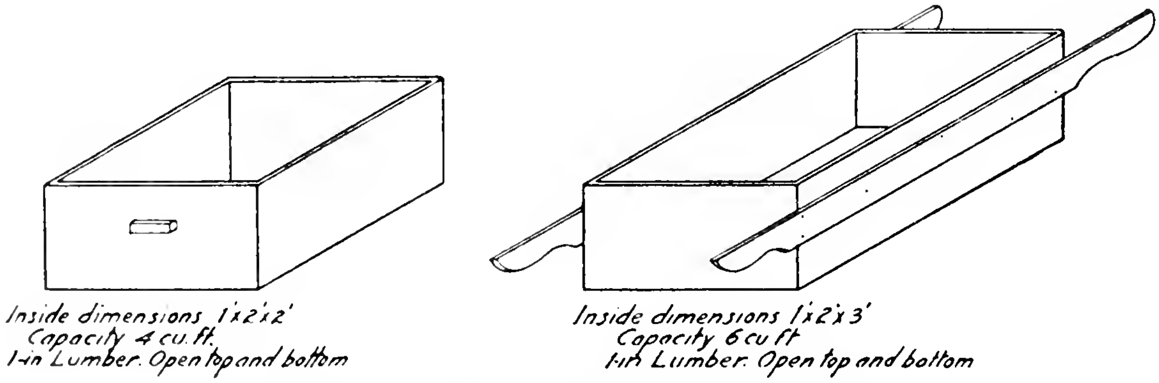

FIG. 135. *Two styles of mixing boxes*

Place the mixing platform as level and firm as possible, convenient to the supply piles of material. Place the measuring box on the platform and measure 2 cubic feet of sand. Remove the box and spread out the sand in a layer about 4 inches thick. Spread one sack of cement uniformly over the sand. Start shoveling this pile into another pile immediately back of one end of the original pile with a turning motion of the shovel so as to mix the sand and cement. Proceed straight through the original pile and then turn around and start where you left off and go back through the new pile in the same way. Go through at least three times. A greater number is better. Next,

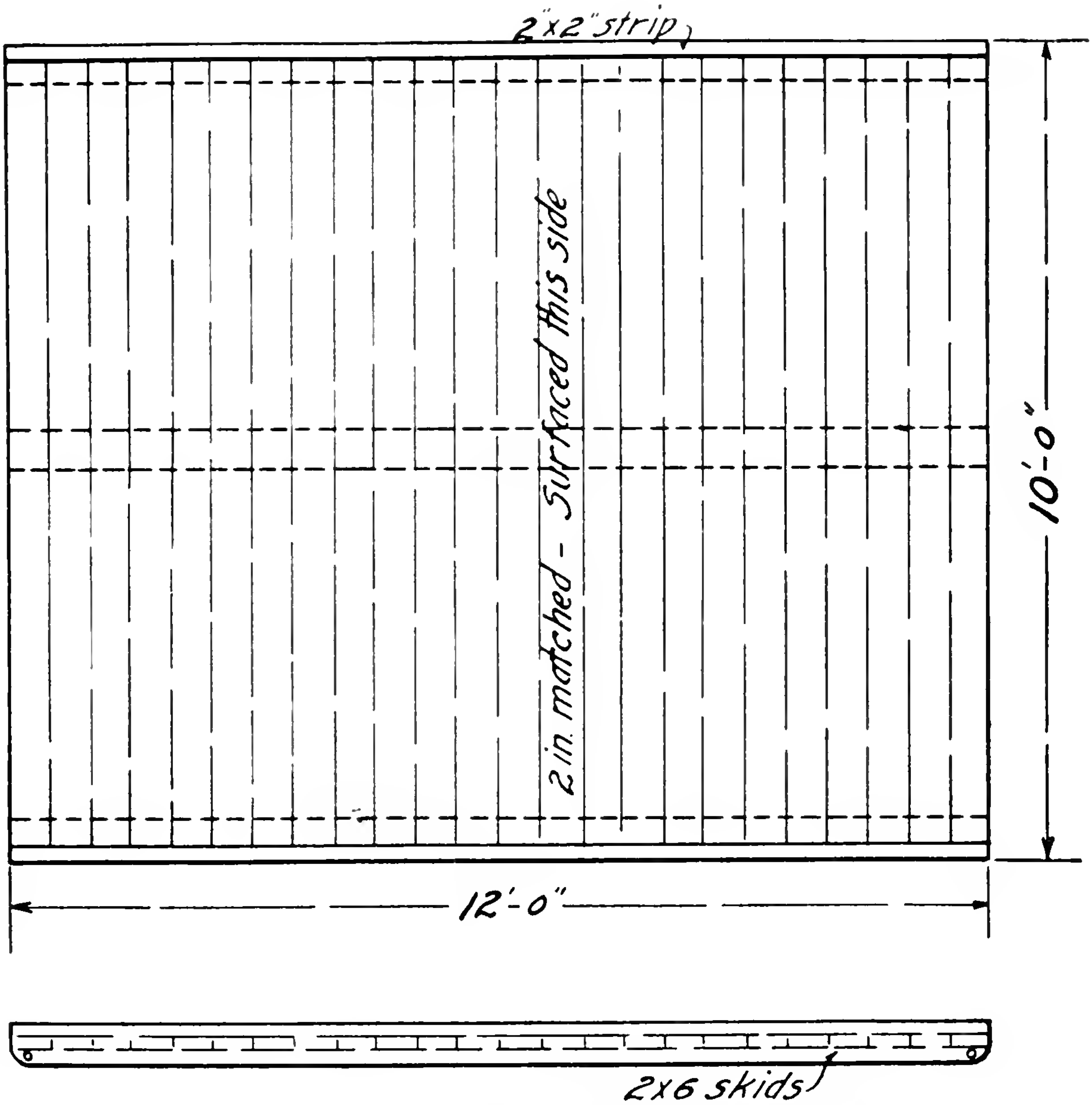

FIG. 136. *Details of construction of a mixing platform*

spread out the mixture and place the measuring box on top. Measure out 4 cubic feet of rock or gravel. Spread this over the surface of the sand and cement and mix as before. Two or three times will do. Now shovel the mixture into a ring-shaped pile and place the water in the center of the ring, not all at once, however. Start with the inner edges of the ring and mix the center first, adding more water as required and being careful that the water does not break through in large quantities and wash the cement out with it. (See Figs. 137 and 138.)

Mechanical mixers. Contractors or others engaged in cement construction ordinarily use mechanical mixers. These are of two kinds. The *continuous mixer* is one in which the materials are placed in the hopper and concrete is continually being delivered, ready mixed for spreading. A poor mixture is frequently secured from this machine for the reason that the materials are not put into it at a uniform rate. The *batch mixer* avoids the fault of the continuous mixer by having the materials measured into the hopper and then the entire batch is mixed and run out before a new one is placed in the machine. Consequently the batch mixer is the more satisfactory. These machines are made in sizes to suit the various kinds of work and are usually operated by a gas engine.

Consistency. The quantity of water added depends on how the concrete or mortar is to be used. Three classes of consistency are in use: moderately wet, that is, just wet enough to run off the shovel or pour easily from a wheelbarrow or bucket; quaking or jelly-like, so that it will tremble when spaded; and dry as damp earth, so that it will hold its shape when squeezed in the hand. The moderately wet mix is used for pouring into forms such as walls, columns, etc., the quaking mix for such class of work as floors, and pavements, and the dry mix is tamped into forms where no reinforcement is used, such as curbing and gutters. The dry mix should never be used when reinforcement is present, because such a mix will not form a good bond with the steel, and the steel is thus free to pull out. Avoid the

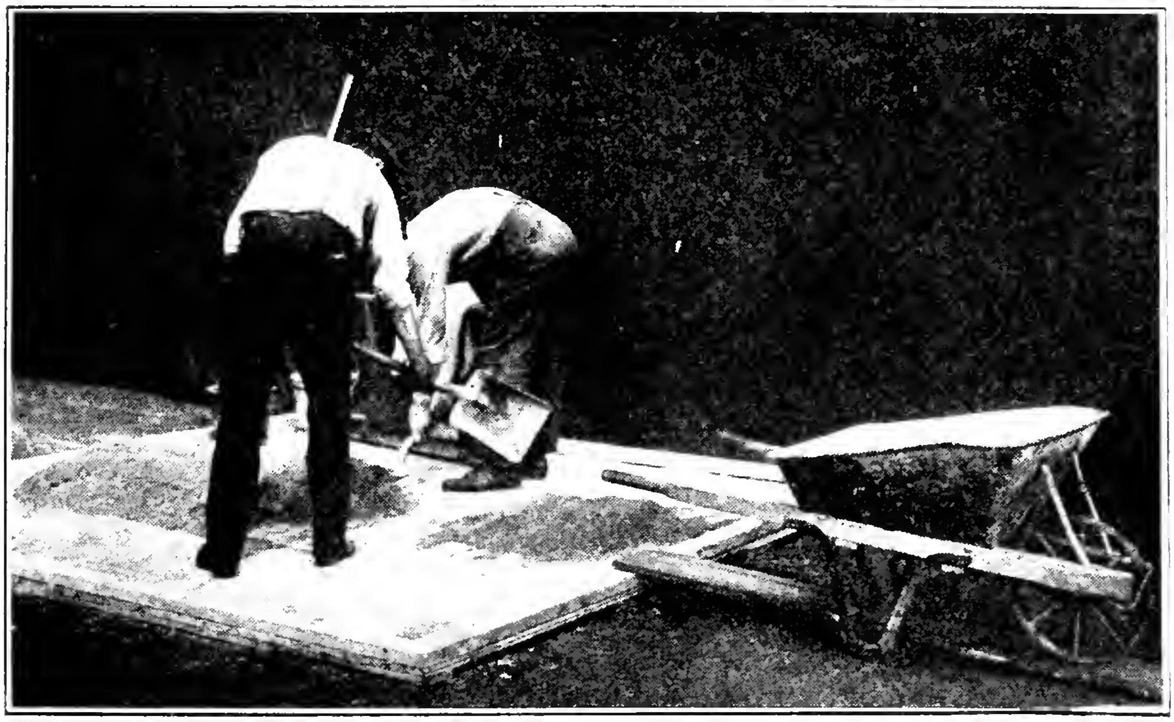

Fig. 137. *Use of a mixing platform*

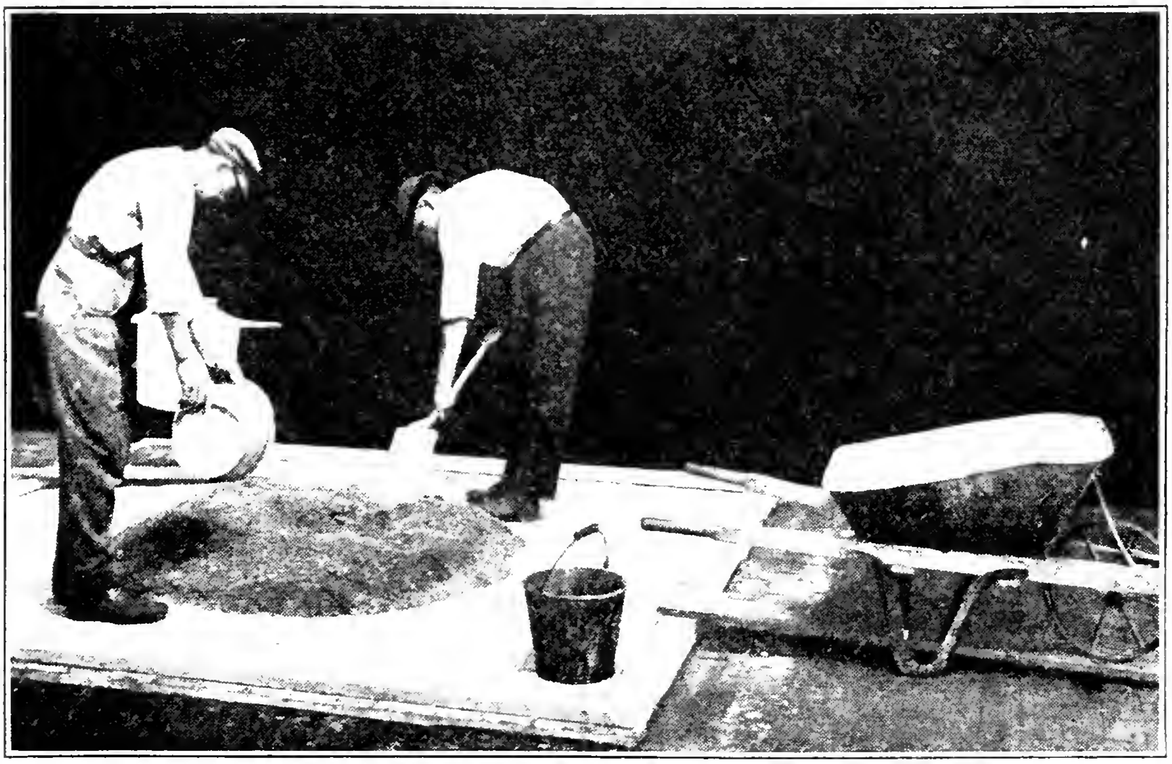

Fig. 138. *Method of adding water*

use of too dry a mix because of the difficulty of proper tamping. The dryer the mix, the faster it sets, which may be an advantage in cold weather, but owing to the difficulty of tamping there are more chances for air space or unfilled portions that will show up when the forms come off. For these reasons a too dry mixed concrete or mortar is not

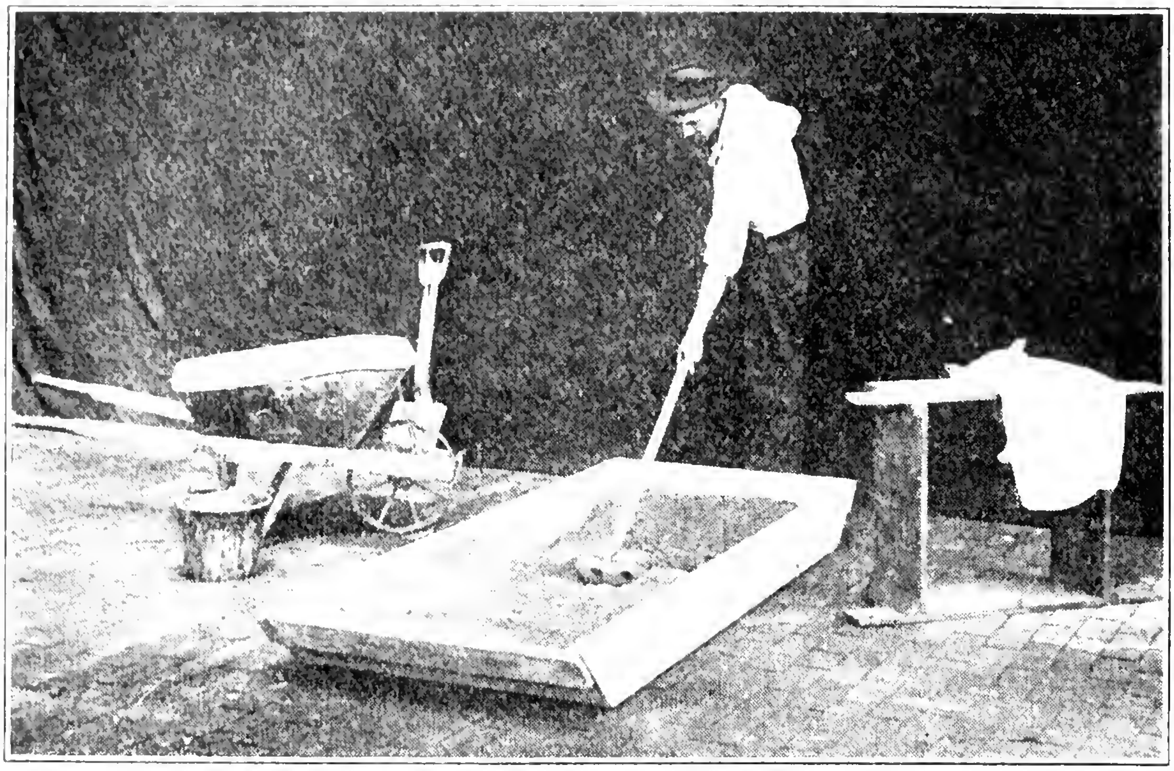

FIG. 139. *Use of a mixing box: a method that will not give as good results as the use of a mixing platform*

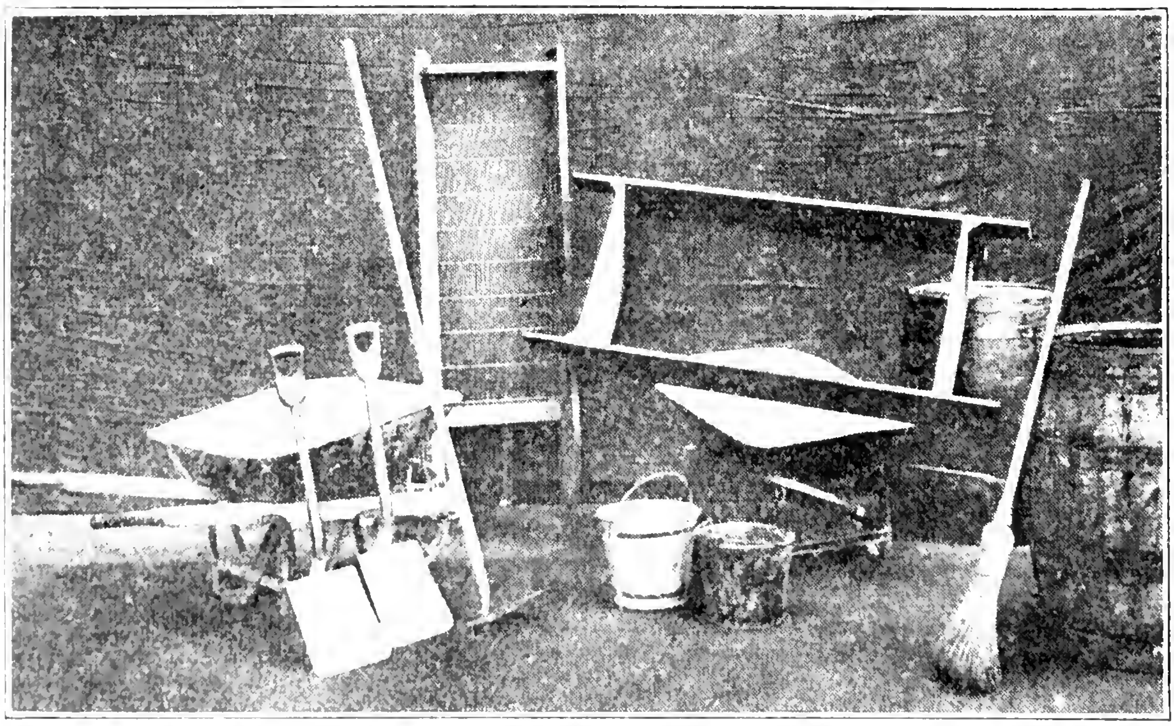

FIG. 140. *Equipment used in concrete mixing*

impervious to water when set up. The jelly-like or quaking mix should be used whenever it is possible, as it is more uniform and gives the highest strength. The moderately wet, although giving lower strength than the quaking, may be necessary in some cases, but very wet or sloppy mixtures should always be avoided, as they give a porous concrete of low strength.

PLACING AND CURING

Forms. *Form* is a name given to the structure which holds concrete in the required shape until it has hardened sufficiently to be self-supporting. Forms should be prepared carefully to give the required shape to the finished concrete. They must have sufficient strength and rigidity to support the weight of the concrete. Concrete weighs approximately 150 pounds per cubic foot and when in the liquid state has a tendency to burst the forms. They should always be water-tight, as the escape of any liquid causes waste of materials, and water flowing out may wash a part of the cement from the aggregate and thus make weak places in the concrete.

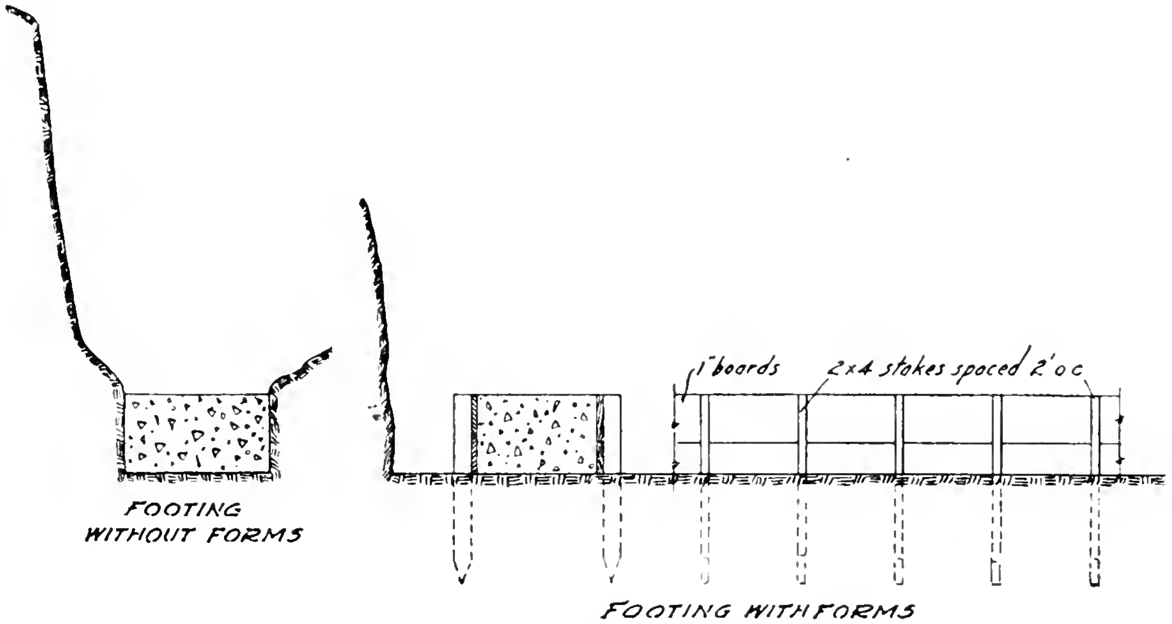

Fig. 141. *Footing construction*

When forms for concrete work are placed underground, the earth bank may be used for one side if it has sufficient solidity to stand vertical. The earth side of the form should have such stability that particles of earth will not fall as the concrete is poured, and it is customary to provide for irregular trimming of the earth by making the wall slightly thicker than when lumber is used on both sides.

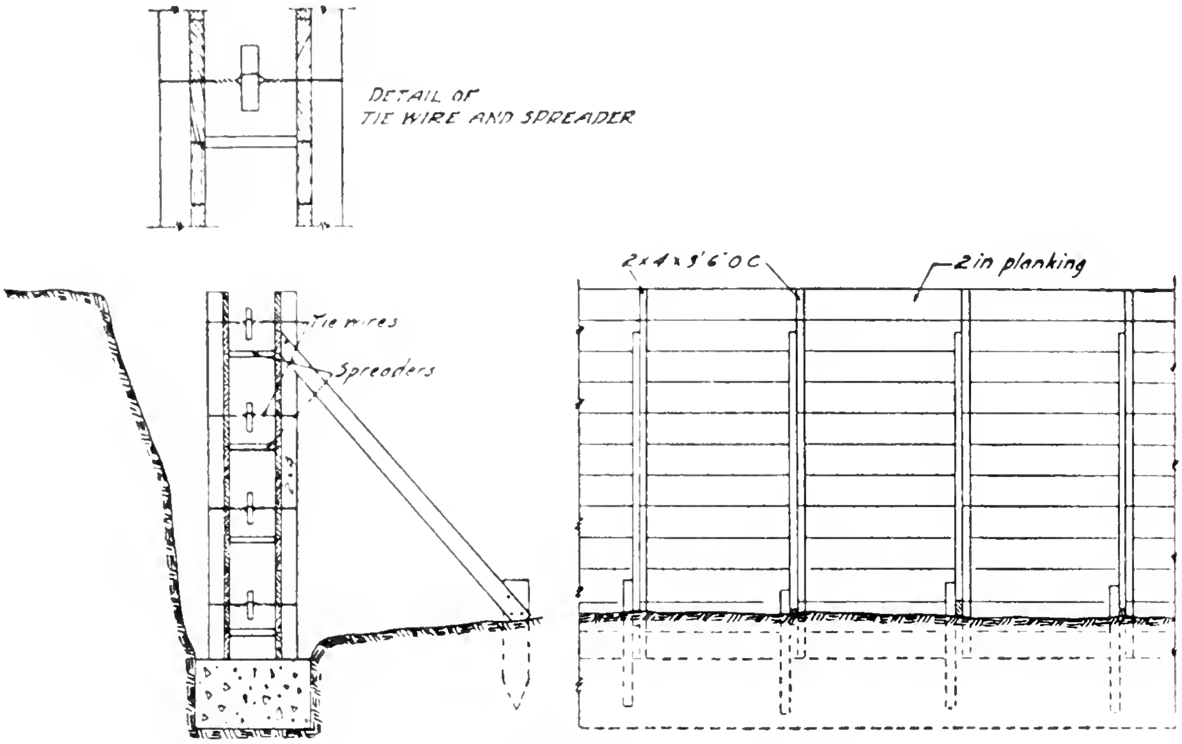

FIG. 142. *Construction of wall forms*

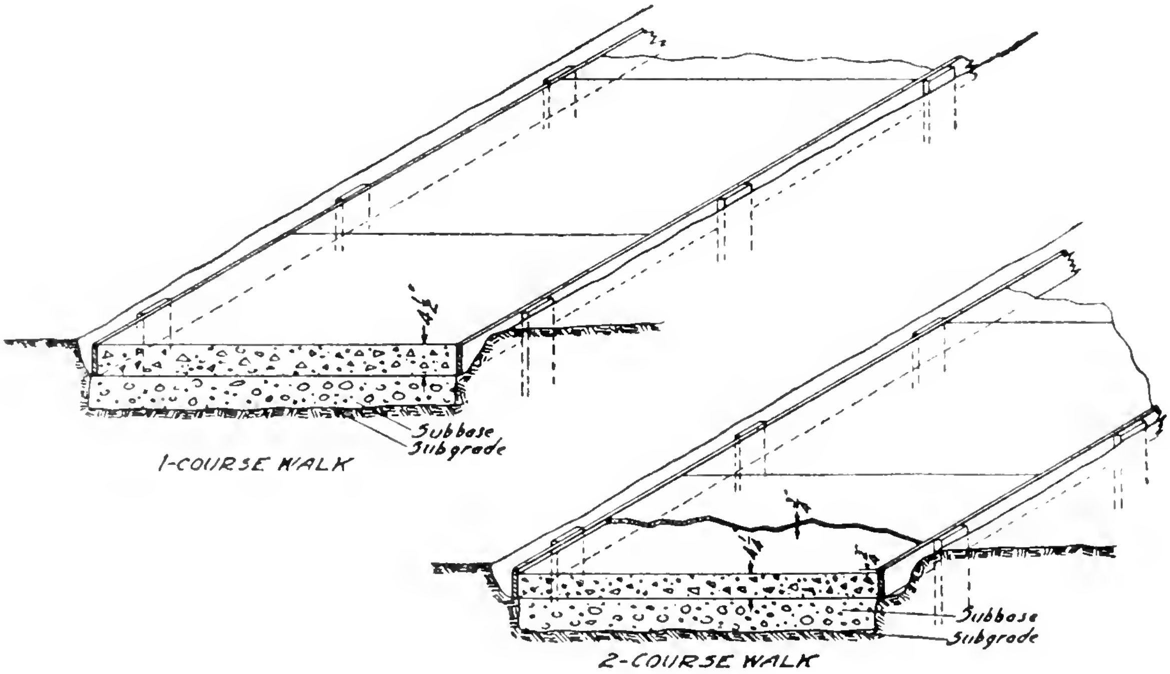

FIG. 143. *Method of construction of one- and two-course sidewalks*

The filling of the forms with concrete is known as *pouring*. When pouring is in progress the forms should be watched carefully for leaks and for any tendency to distort or give way.

Placing. If the mixing platform is near enough, the concrete may be shoveled directly into place in the forms; if not, it may be transported in wheelbarrows, slid down chutes, or hoisted in buckets. In any case the batches should be mixed small enough so that the whole batch can be used within thirty minutes, for cement mixtures take on their initial set in about this length of time, and, if disturbed afterward, may never attain their full strength. If the batch has been mixed with water over thirty minutes, no attempt should be made to add more water and remix, as this

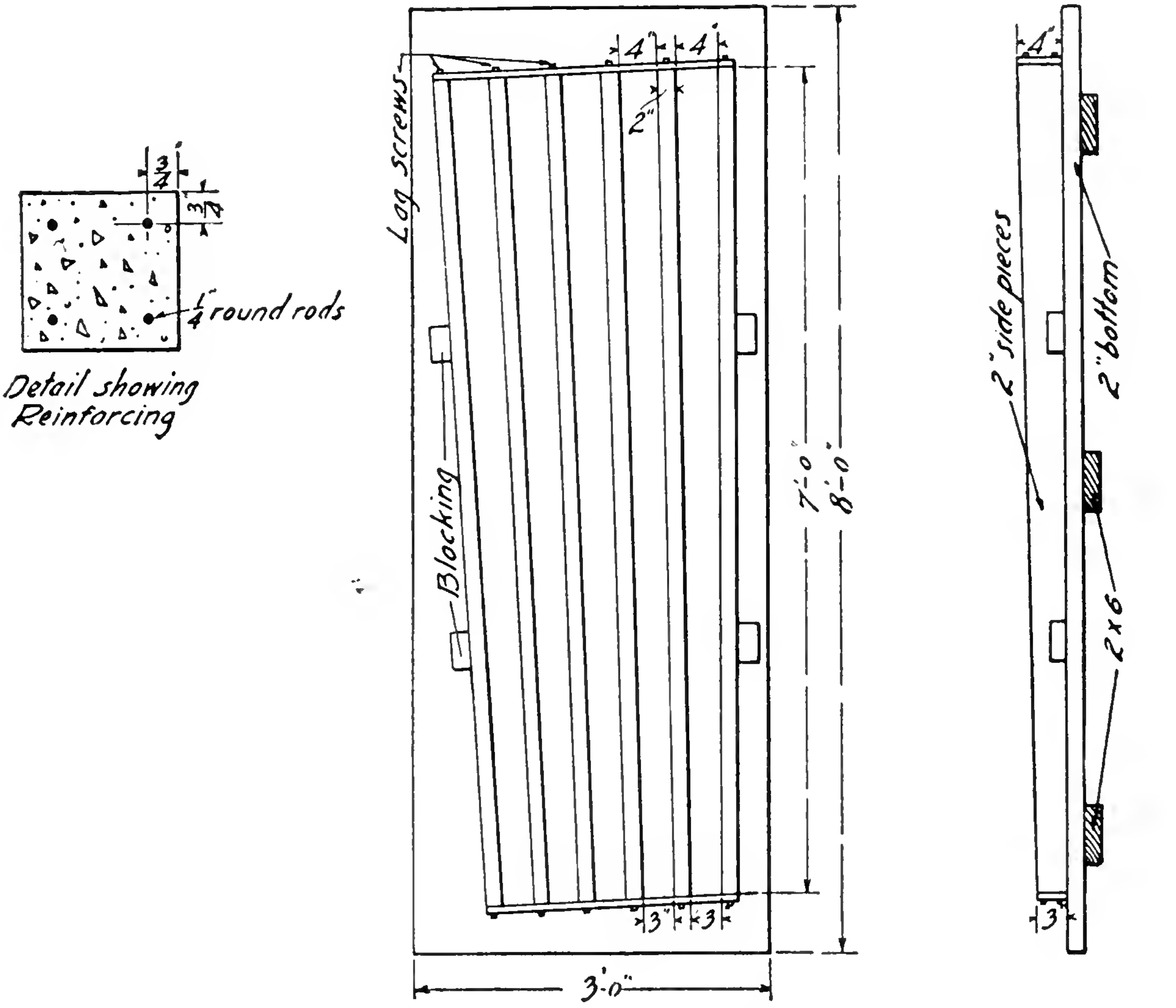

FIG. 144. *Fence-post gang-molds*

so-called regaging cannot restore the setting powers. While being placed into forms the concrete should be frequently puddled or rammed down with a stick or shovel, and a shovel should be forced down into the mixture next to the face of the form to insure a good flow to all parts and a good surface contact between the concrete and the form. This applies especially to such work as walls. Keep the forms wet down ahead of placing, for this insures good contact and easy flow of the concrete.

Proper curing. Cement work, once placed, must be properly protected from too rapid drying. Surfaces should be wet as frequently as possible, twice a day at least for four days, and protected from the hot sun by a covering of canvas, a shading of building paper, old sacks, or brush, or a covering of a layer of sand. Too rapid drying lowers the ultimate strength and creates shrinkage cracks. With the dry mix especially it is necessary to provide ample protection from the action of the hot sun and to supply moisture for several days in order that the cement may complete its chemical action properly. The longer cement work is kept wet, the greater its ultimate strength will be, even for several months. Keeping work wet thirty days will, in many cases, pay for the trouble by increasing the strength.

Freezing. Concrete work should not be attempted in freezing weather if it can be done at other times. If concrete freezes within forty-eight hours after it is mixed, it may lose its setting powers, which will necessitate its being taken out and replaced. If it is necessary to place concrete in freezing weather, it should be protected by a covering of canvas, straw, or manure. In mixing, both the water and the aggregate should be heated, care being taken to see that there are no frozen lumps in the mix and no ice in the forms. If practicable, temporary heat by means of stoves or salamanders should be provided until the danger of freezing is past. Salt is sometimes used to lower the freezing point of the mixture. Protecting coverings should be left on the concrete for approximately five days to give it an opportunity to harden.

Removal of forms. Too early removal of forms may seriously injure concrete work. For such work as vertical walls where the stresses due to supporting its own weight are not great, three days are a safe limit in clear, dry weather. The other extreme may frequently be as long as five weeks for reinforced work where the structure must support itself, and, if the weather is extremely cold, longer periods may be necessary. Beams, slabs, and arches are examples. It is evident that it requires more lumber for form work to keep a job moving when forms cannot be removed and used over again; hence it is profitable to remove forms as soon as it is safe.

SPECIAL REQUIREMENTS AND STRENGTH

Prevention of cracks. Any movement of the cement mass after casting will cause cracks. Consequently the soil on which cement walls or slabs are to be placed should be of sufficient solidity not to settle or be moved by freezing and thawing. For this purpose good drainage is necessary. These conditions are secured by means of tamping the ground thoroughly and then placing a sub-base of sand or cinders. Sidewalks, floors, and smaller work should have from 4 to 6 inches of sand or cinders thoroughly rammed underneath. The walls should have a similar foundation unless they extend deep into the ground. Flat cement work similar to floors, sidewalks, etc., should be cut in squares from 3 to 6 feet on a side with a groover. The object of this is to weaken the slabs slightly at the grooves so that if cracks occur they will follow the grooves. Slab work exposed to changes of temperature should be cut through the base course to permit contraction. A quarter-inch joint is frequently left every 12 or 18 feet, the opening being filled with tar or building felt.

Waterproofing. Tanks, watering troughs, and cisterns need to be water-tight. It is very difficult to obtain absolutely water-tight concrete, but with proper care it is possible to obtain a nearly impervious mixture. This requires a rich mixture such as 1 : 2 : 3 or 1 : 2 : 4, mixed with sufficient water but not an excess, placed carefully, and well puddled and spaded in the forms. The next consideration is the avoidance of cracks. Cracks come from shrinkage or from settlement; therefore exercise care in proper curing and in providing ample foundations. With adequate attention to these things, practically water-tight work will result without any further provision. Many waterproofing compounds are on the market which are mixed with concrete and are of some benefit, but are unnecessary. Cracks, if they develop, may be filled with a rich mortar.

Bonding old and new concrete. When work cannot be completed at one placing, the concrete placed the first day will be set and hard when the work is continued. To obtain a good bond and make a water-tight joint between old and new work, special precautions are necessary. The face of the old work should be thoroughly cleaned by scrubbing with a wire brush or stiff broom. Then it should be wet and a coat of neat cement applied and the new work poured on this before it has a chance to set. It is possible to obtain a good joint by inserting a 2″×4″ in the old work when finishing the day's run and removing it when the work

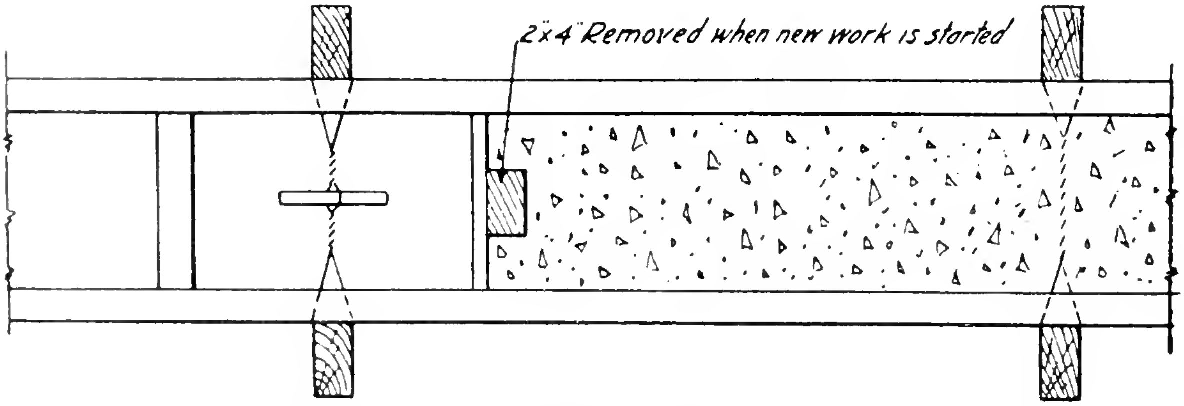

FIG. 145. *Wall section showing the use of 2″ × 4″ insert*

is continued, making a tongue and-groove joint as indicated in Figure 145.

Reinforcement. Where a thin wall of concrete with great strength is desired, steel in the form of rods or special design is placed in the forms before casting (Fig. 146). The object of reinforcement is to increase the tensile strength, which is the weak part in cement work. The concrete itself has sufficient strength to resist the compressive strains. When reinforced work is necessary, advice should be secured from an experienced person as to the kind and method of reinforcing to be used.

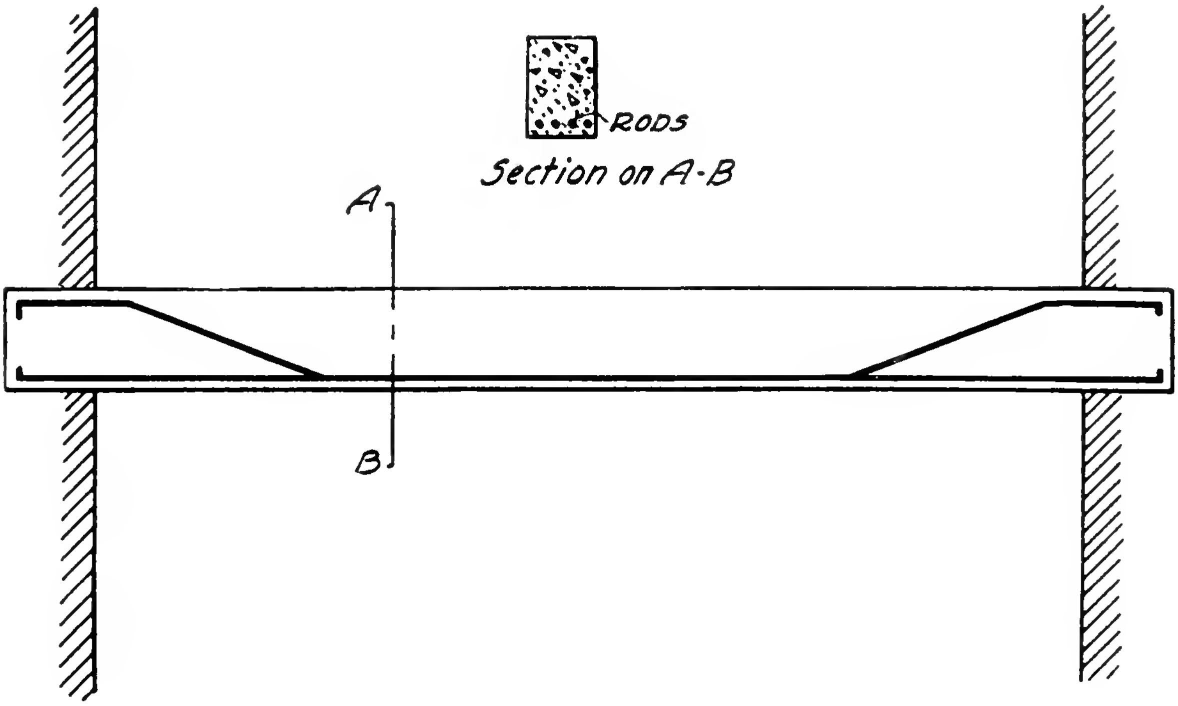

FIG. 146. *Typical reinforced concrete beam*

Strength of concrete. The strength of concrete is dependent upon the mixture, the age, the condition of the materials used, and the method of curing. Tensile strength is neglected and compressive strength is the only thing considered, as concrete structures which are not reinforced are usually so built that the stresses are only compressive. The actual load which is to be carried is much less than the load required to crush the completed concrete. As an example, 1 : 2 : 4 concrete will safely carry from 600 to 700 pounds per square inch under ordinary conditions, but the actual crushing strength of the same mixture, when fifty days of age, is approximately 2,000 pounds, as a factor of safety of approximately 3 is considered necessary. A 1 : 3 : 6 mixture would safely carry 500 pounds per square inch, while the same mixture at fifty days of age would require 1,600 pounds to crush it. The strength of reinforced concrete depends upon the quantity of steel used and the area of the cross sections.

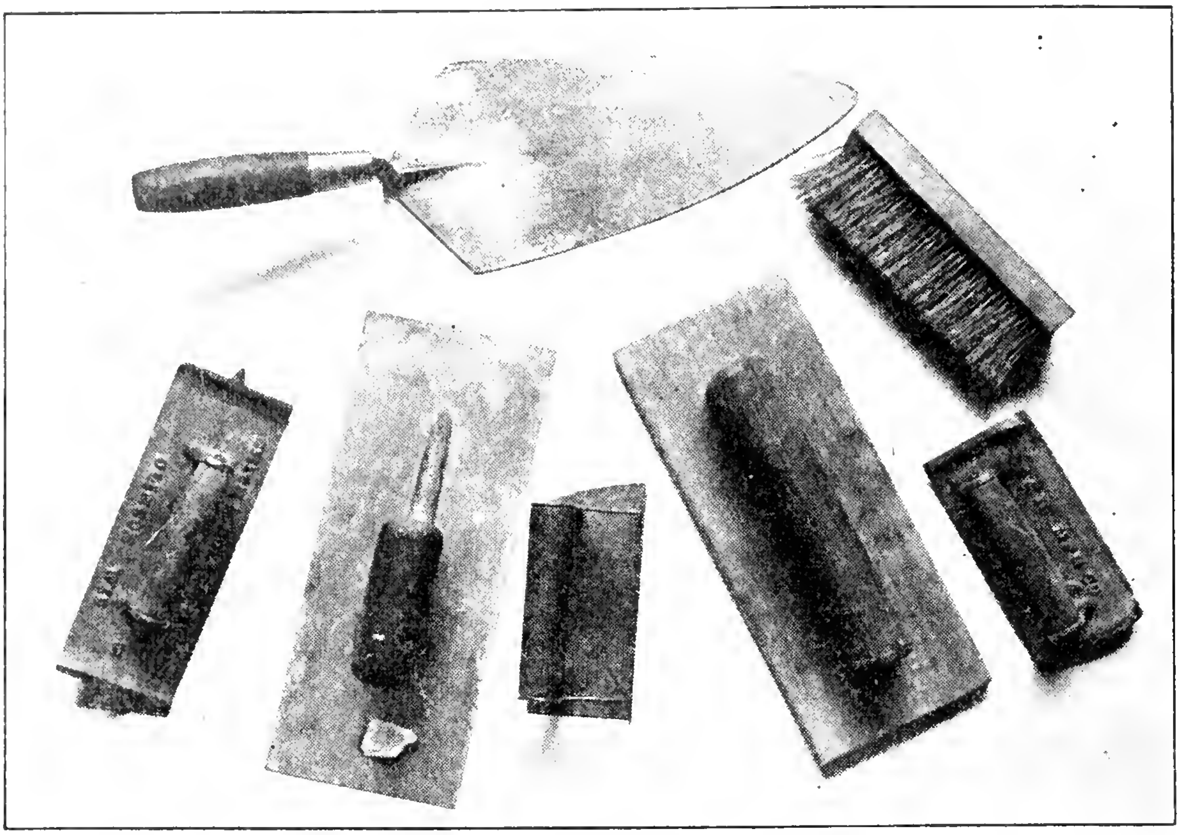

FIG. 147. *A group of cement finishing tools*

FINISH

Trowel finish. When freshly poured concrete is rubbed with a metal trowel, the sand is forced down and the cement brought to the surface, which gives it a smooth, glossy appearance known as a *trowel finish*. (See Fig. 148.)

Float finish. If freshly poured concrete is rubbed with a piece of wood or soft material when quite wet, the sand is brought to the surface and presents a rough or grainy surface known as a *float finish*. While the float finish is not so pleasing to the eye as the trowel finish, it is not so

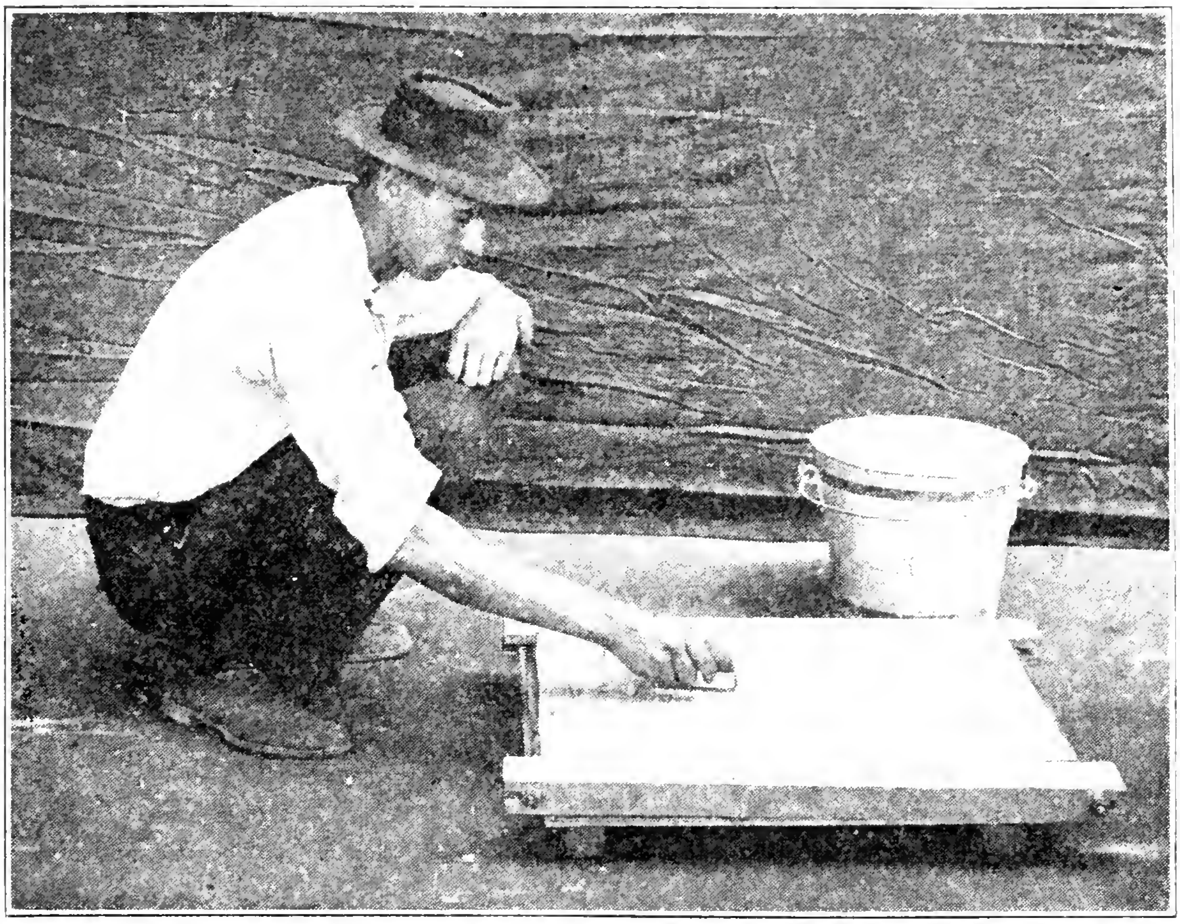

FIG. 148. *Showing the use of the metal finishing trowel*

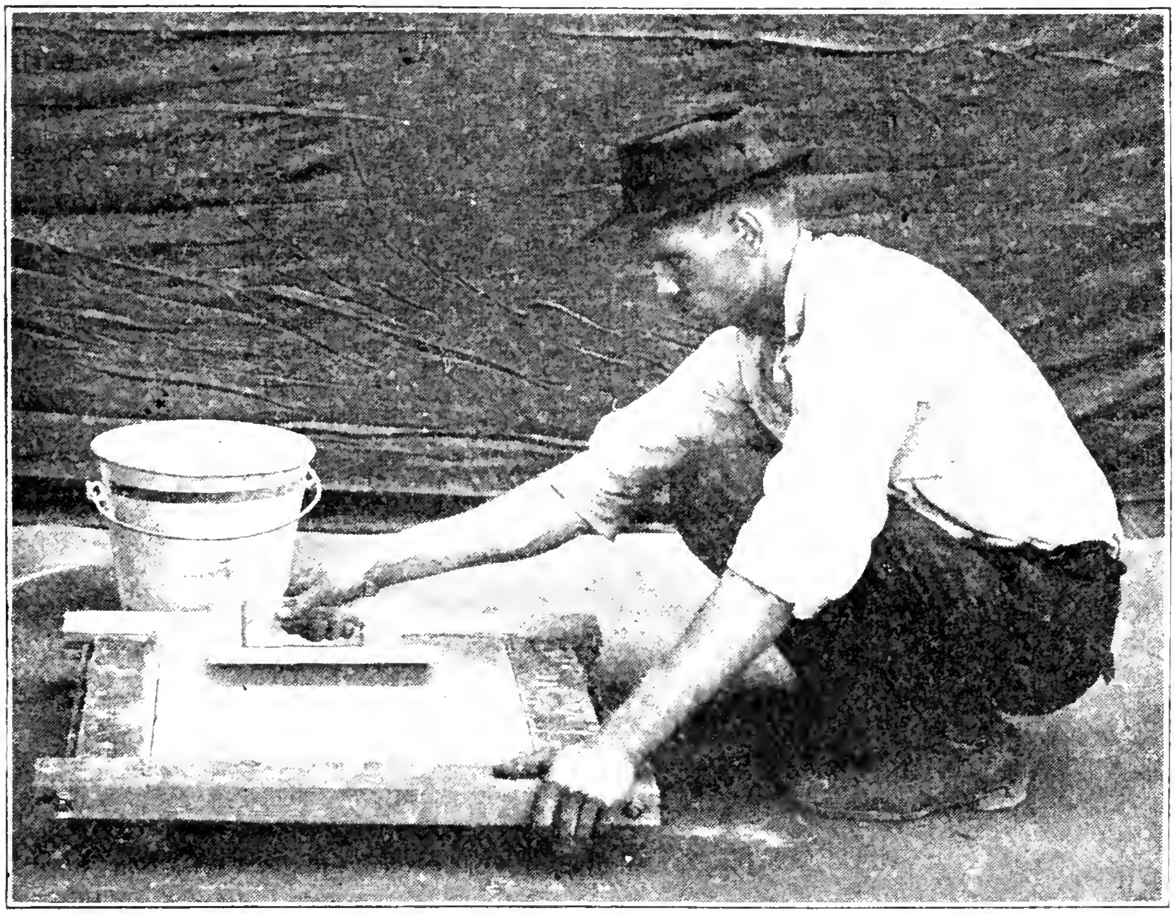

FIG. 149 *Showing the use of a wood-float finisher*

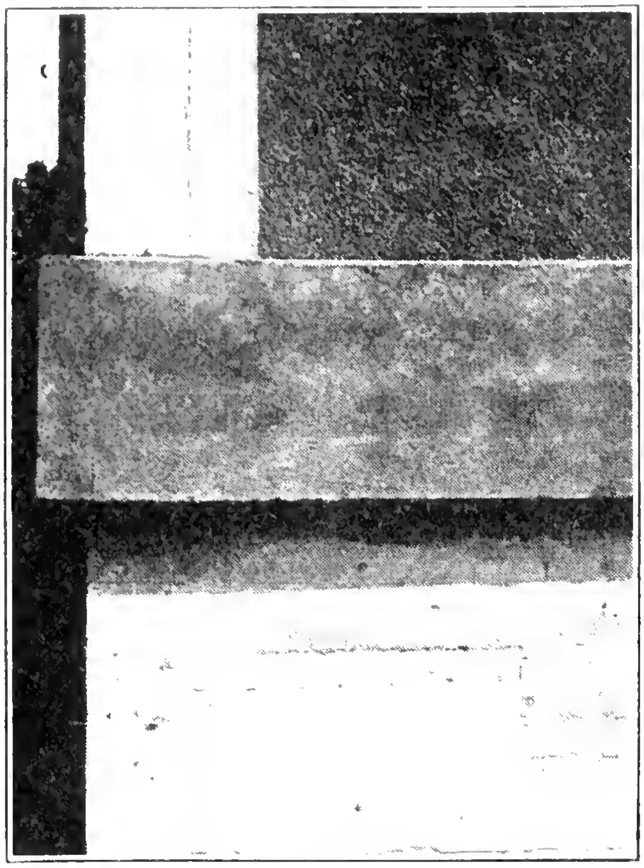

Fig. 150. *Showing the spatter-coat finish on upper wall, carpet-covered float finish on water table, and the surface of lower wall and columns as left by the forms*

slippery and is more desirable for steps and sidewalks. (See Fig. 149.)

Spading. Vertical surfaces of concrete which has been placed in the form can be kept smooth at the time of casting by means of a spade or flat steel tool run next the form and worked back and forth. This forces the coarser materials back into the wall and brings the cement to the surface and is known as *spading*.

Coloring. When it is desired to color the face

Fig. 151. *Method of applying spatter coat*

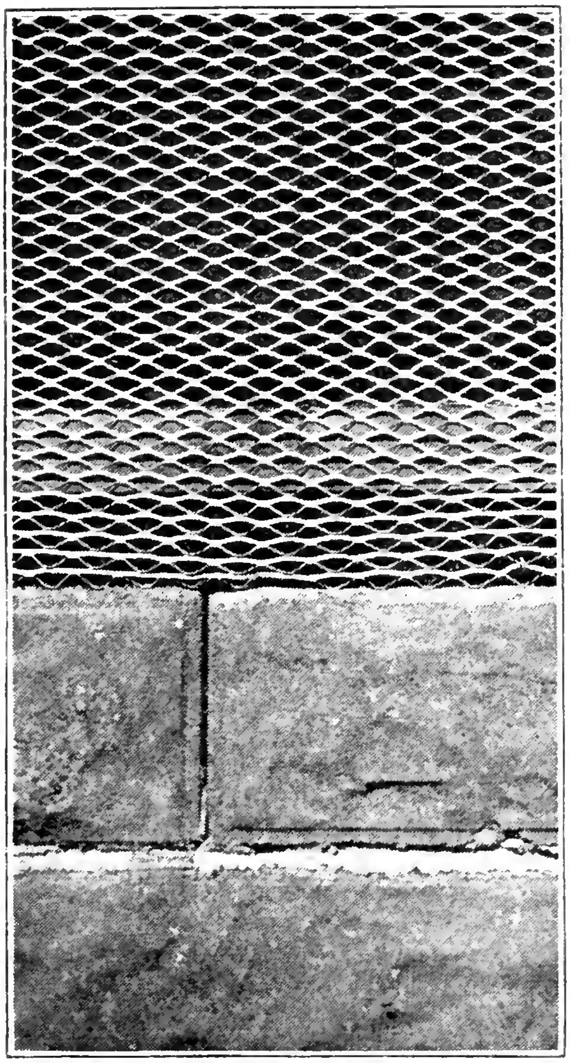

FIG. 152. *Metal lath as used to hold stucco coat*

FIG. 153. *Metal lath with the scratch coat applied*

of a wall, a thin sheet of metal is placed near the form and the intervening space is filled with a cement mortar which has previously been prepared by being mixed with the proper coloring matter. The metal is pulled up as the pouring progresses.

Spatter finish. If a rough finish is desired, it may be secured by means of cement mortar mixed and thrown against the face of the wall with a wire or willow brush after the wall has been thoroughly cleaned and wet. This finish is known as a *spatter finish* and looks better when coarse sand and small pebbles have been mixed with the mortar. (See Fig. 151.)

Stucco finish. A wall or other structure may be given the appearance of concrete construction or a cement finish by means of first covering it with wood or metal lath (Fig. 152) and then covering this lath with a ½-inch coat of concrete mortar, known as a scratch coat (Fig. 153), then a thinner or intermediate coat, and a finish coat which may be given a trowel, float, or spatter finish. When the trowel or float finish is desired, the finish coat should be from ½ to 1 inch thick. Surface may also be finished by removal of the forms before the concrete has thoroughly set and rubbing with a float and sand, a brick of natural stone, or carborundum. A surface may also be finished with a sand blast or with stonecutter's tools.

SUMMARY

Cement is of two general classes, natural and Portland cement.

Portland is the better for the reason that in its manufacture the predominating elements for compounding a good cement are definitely known.

When cement is stored, it must be placed on a dry floor and protected on all sides from contact with moisture.

Cement is used in neat cement, in cement mortar, and in concrete.

A good aggregate is as important as a good cement.

Bank-run gravel is inferior to screened sand and gravel properly mixed.

In the ordinary classes of concrete work the proportion of mixtures as given by the table on page 138 are used.

Measuring devices are necessary in mixing.

Quaking consistency is recommended for most work.

Batches must be used before the initial set.

Spading is essential if smooth work is desired.

Curing is as essential as any of the other steps in the manufacture of concrete if proper strength is to be secured and rapid shrinkage avoided.

Freezing may ruin concrete, but concrete can be laid in freezing weather if proper precautions are taken.

Concrete structures may be injured by removal of the forms too soon.

Concrete may be made practically water-tight by proper methods of mixing.

Steel and concrete form an economical combination.

Sightly and permanent concrete construction can be secured only by the use of standard cement, carefully stored and thoroughly mixed in the proper proportions with clear water free from alkali or acid, and well-graded, strong, clean aggregate, carefully placed in strong, smooth forms and protected from freezing, hot suns, and dry winds during the process of hardening.

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CHAPTER IX

BUILDING MATERIALS

Materials used in the construction of buildings vary with time and locality. Climatic conditions, the nearest supply, relative cost, and the class of labor available are considerations in all cases. Modern developments such as prepared roofings, insulating materials, and special forms of tile and concrete are evidence of a change from the practices of the pioneer. A detailed discussion of all the materials used in building construction would be too extended for this chapter, and where the importance of an item warrants it discussion has been given in a preceding chapter. Wood and concrete are each treated separately.

VALUE OF VARIOUS MATERIALS

Stone. At one time stone was considered the best material for foundations, and it is still used extensively for that purpose in sections of the country where the supply is near at hand, abundant, and, in consequence, cheap. Common or rubble stone set together with mortar is the usual practice for either walls or foundations in rural communities. Because of the cost, cut stone is seldom used except for three or four courses above the grade line.

Brick and tile. There are many grades of brick, the quality depending on composition and process of manufacture. Sizes are not standardized, but range from 2″×3¾″×7¾″ to 2½″×4½″×9″. Brick may be made of clay, clay and sand, sand and lime, or sand and cement, mixed with water, pressed into shape, and cured. The ordinary *clay brick* is frequently called the mud brick. While it is the cheapest, it is likely to be irregular in size and shape. A *pressed brick*, or hydraulic pressed brick, made of any of the above materials, comes from the factory very regular in shape and true to dimensions. *Fire brick* is pressed brick made of fire clay. It is used in fire-box lining and comes in slightly larger sizes than common building brick. *Paving brick* is a vitrified clay brick which has been annealed. It does not conform to regular brick dimensions. *Sand-lime brick* is pressed to shape under a pressure of about 175 tons per brick and cured in a steam bath. *Glazed* or *enameled brick* may be any type of brick which has been given a special hard and polished surface. Such bricks are made in regular and special sizes and some special shapes and are used where their impervious or ornamental qualities are an advantage. *Facing* or *finishing bricks* of clay are of any type, but are selected from the kilns with the idea of getting an even run of color. A single kiln may furnish several varieties of finish or face brick.

Tile made of either clay or concrete is made much the same as brick, the difference lying in the mechanical form of the product. Hollow tile is used extensively for foundations, walls, and interior partitions.

For concrete and cement mortar, see chapter viii.

Wall sidings. The oldest and most common material for the siding of ordinary buildings is wood. There are a number of milled shapes of siding which in the order of their popularity are: *shiplap*, *rustic*, *drop siding*, *beveled siding*, and *long-beveled drop siding*. A cross between shiplap and drop siding is rustic; and one between drop siding and beveled siding, long-beveled drop siding. The last makes a very desirable sheeting for light buildings, such as poultry houses, garages, and machine sheds. Its appearance is that of beveled siding, and there is no reason why it cannot replace this for house surfacing. See Figures 118 to 124, pages 117 to 120.

Stucco. The popularity of cement has encroached to some extent upon that of lumber as an outside covering for buildings. For composition and application of stucco, see chapter viii.

Metal sidings. Thin sheets of galvanized iron or tin may be used as an outside covering for some buildings. They are reasonably wind-tight, but transmit heat or cold and when not kept painted deteriorate rapidly.

Insulating materials. Insulating materials are used in the construction of walls and floors to minimize the changes due to outside temperatures. In houses and barns a higher inside temperature is the object; in ice houses, the reverse.

Paper. The lightest and cheapest kind of insulating material is paper treated with various preparations. *Rosin-sized paper* is short-lived. *Tar paper* is better, and *asphalt-saturated* or *coated paper* still more satisfactory. Their virtue lies in the length of time they will "stand up." One which dries out and disintegrates in a short time is exceedingly poor.

Felt. Next in weight of the insulating materials are those known as *felts* or *quilts.* These are made of hair, of sea moss, of flax straw, or of various combinations, some with a light short-lived stock of paper on one or both sides to facilitate handling and placing. Another kind is a sheet made of flax straw or tow which has been rolled into this form after having been soaked for some time. It is very stable, is not attractive to mice and rats, and possesses the long life of the flax fiber. It is highly desirable for insulating purposes and may be had in thicknesses up to 4 inches. This last is used in the insulation of ice houses and dry kilns. *Lith* is one of the standard insulating articles on the market. All fibrous insulations must be kept dry; if allowed to become water-soaked, they are difficult to dry and lose a large proportion of their insulating qualities.

Cork. One of the best—though, at the same time, one of the most expensive—insulating materials is cork, either in the ground form or pressed into sheets or bricks. It has a low absorption coefficient, and even when directly exposed to water takes up a very small quantity.

Glass. Ordinary glass, known as *window glass*, is manufactured by a blowing and rolling process. It is blown into the shape of a cylinder, then cut and rolled out on a smooth plate It is naturally possessed of many defects, such as bubbles and waves, as well as being uneven in thickness. This glass is on the market as single-strength (S. S.), supposed to be $\frac{1}{16}$ inch thick, and double-strength (D. S.), supposed to be $\frac{1}{8}$ inch in thickness. The quality of glass is indicated as AA, A, and B. The B quality is the poorest that may be marketed. It is used ordinarily in cellar sash. Regular stock is cut to sizes of even inches, and is sold by the box, as nearly 50 square feet to a box as the size of panes will make. Single-strength is limited in size to 34 by 50 inches, double strength to 60×70 inches.

Plate glass. Plate glass is manufactured by a rolling process and subsequently ground to a perfect surface. It is to be had in thicknesses from $\frac{3}{16}$ to $\frac{5}{16}$ inch, and in any size desired.

Special glass. Special glass, such as *crown glass*, may be had on order. It is made of better materials and more nearly free from defects. *Ground*, *prismatic*, *rib*, and *wire glass* may be had in any size up to 4 by 10 feet. It should be noted that the price of glass, per square foot, increases very rapidly with the size of the pane.

Nails and screws. *Nails.* Nails are made in a variety of materials and shapes and weights. They may be had of steel, wrought iron, brass, or copper, and in finish plain, galvanized, or cement-coated. The old style of cut nails is no longer manufactured; they have been replaced by the wire nail, though the latter has not the same holding power.

Nails are designated as "penny," which originally indicated the number of pennyweights of metal which the nail actually contained. The improved quality of materials has allowed the reduction of weight, but the designation is unchanged. Steel or wire nails run in weights from 2 to 60 penny and are known as common, flooring, finishing, casing, shingle, slate, box, and roofing. The brass and copper nails are of various shapes and are not standardized.

DIMENSION AND APPROXIMATE NUMBER PER POUND OF STEEL WIRE NAILS SUITABLE FOR GENERAL USE

Trade Name	Length in Inches	American Wire Gauge	No. per Pound
3d fine	1⅛	No. 16	920
3d common	1¼	No. 14½	615
4d common	1½	No. 13	322
6d common	2	No. 12	200
8d common	2½	No. 10½	106
10d common	3	No. 9½	74
12d common	3¼	No. 9	57
16d common	3½	No. 8	46
20d common	4	No. 6	29
30d common	4½	No. 5	23
6d casing	2	No. 13	260
8d casing	2½	No. 13	160
10d casing	3	No. 11	108
4d finish	1½	No. 16	767
6d finish	2	No. 14	359
8d finish	2½	No. 13	214
10d finish	3	No. 12	134
3d shingle	1¼	No. 13	429
6d flooring	2	No. 11	151
8d flooring	2½	No. 10	98
10d flooring	3	No. 9	66
4d box	1½	No. 15	550
6d box	2	No. 13	250

Nails are originally packed in kegs of 100 pounds each. In the selection of a nail for any particular use, the length should be two and a half to three times the thickness of the part to be secured. Another element which enters into the choice of a nail is the nature of the wood. A large nail will split, while a lighter-gauge nail, though shorter, will not split and so will hold with its full strength. It is difficult to specify the exact number of nails for any job without knowing the nature of the timber to be used. It is, at times, necessary to drill a hole for a nail in order to avoid splitting. The galvanized and copper nails are used for wood shingles and for slates.

Screws. Flat-head screws are sold by the gross. The diameter of the screw near the head is determined by number, which increases with the diameter and length. The head is included in the length, and the number corresponds to the American Screw Gauge Table. The following table gives the number and length of flat-head screws carried in stock, with the various numbers available for the same length:

Length of Screw in Inches	Available Numbers in Each Length	Length of Screw in Inches	Available Numbers in Each Length
¼	0– 4 inclusive	2	5–24 inclusive
⅜	0– 9 “	2¼	5–24 “
½	1–12 “	2½	5–24 “
⅝	1–14 “	2¾	6–24 “
¾	2–16 “	3	6–26 “
⅞	2–16 “	3½	8–26 “
1	4–20 “	4	8–30 “
1¼	4–24 “	4½	12–30 “
1½	4–24 “	5	12–30 “
1¾	5–24 “	6	12–30 “

EQUIVALENT OF AMERICAN SCREW GAUGE TABLE IN DECIMALS OF AN INCH

0	.0578	5	.1236	10	.1894	15	.2552	22	.3474
1	.0710	6	.1368	11	.2036	16	.2684	24	.3737
2	.0842	7	.1500	12	.2158	17	.2816	26	.4000
3	.0973	8	.1631	13	.2289	18	.2947	28	.4263
4	.1105	9	.1763	14	.2421	20	.3210	30	.4526

Flooring. Tamped earth or clay has proved a very satisfactory flooring for some farm buildings, and cement is being used more and more extensively, but wooden floors of various types are and probably will for some time continue to be the most common.

House floors. In the early settlements of any part of the country house floors were made of whatever material was most available. White pine in 6-inch widths, dressed and matched, has had very wide use. This has been replaced largely within recent years by yellow pine and Washington fir. These should be of vertical-grain stock. They present good wearing surfaces, are hard, do not splinter, but shrink and swell somewhat. They may be oiled, painted, or varnished. Where a hardwood floor is desired, oak, maple, or birch gives good results. Oak, being open-grained, calls for special treatment in finishing. Both maple and birch are close-grained and stand hard usage, but it is practically impossible to maintain a finish upon them. Any finish, when applied to a surface, must penetrate deep enough to make a distinct bond between the floor and the protective covering.

Barn floors. Plank floors have been used in barns for many years and have the advantage of cheapness and ease of repair may be made of 2″ × 4″'s or 2″ × 3″'s placed on edge and or renewal. A better, more sanitary, and more durable floor separated by a lath spaced 2 feet and the cracks between filled with pitch. This floor is tight, solid, and good for many years (Fig. 154). Creosoted wood blocks such as are used for street paving, laid according to standard paving practice, are very good. Cork brick or blocks laid in the same manner are tight, sanitary, and not too hard for use as a stable floor. Expense is the chief objection. Concrete floors are permanent, sanitary, and easily cleaned. A replaceable wood covering on concrete has proved quite satisfactory.

Roofing. *Shakes.* The oldest roofing extensively used in this country was shakes. These were slabs of pine, cedar, redwood, or cypress, 6 to 8 inches wide, 20 to 30 inches long, and ½ to ¾ inch thick. They were split out of straight-grain timbers and were very durable, in many cases serving from fifty to eighty years.

Shingles. At the present the *wood shingle* is most popular. It is wedge-shaped and 16 or 18 inches long. Six common shingles stacked with the butts together will measure 2 inches. They are commercially known as 6 to 2 shingles. A heavier shingle is known as 5 to 2. The wood used is cedar, white pine, and cypress, favored in the order named.

The life of a shingle is materially extended if it is dipped in creosote oil or a paint oil before being laid.

Asphalt shingles. Another shingle is made of asphalt-saturated felt, cut in sizes about 8 × 12¾ or multiples of

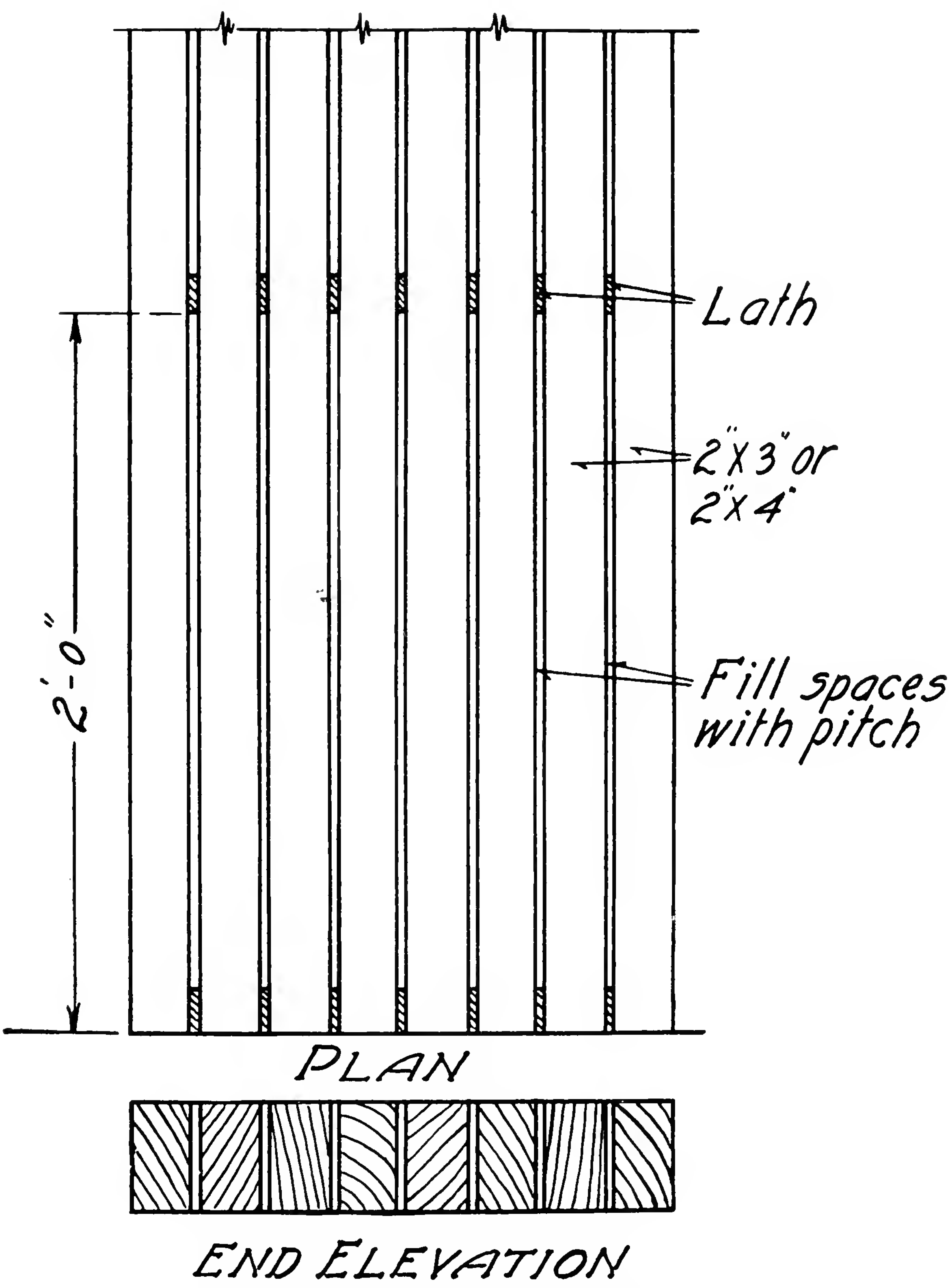

FIG. 154. *A durable and sanitary stall floor made of wood and pitch*

this size These are given color by chips of slate or fine sand of an even color rolled into the surface. They are very durable and the color is fast.

Asbestos shingles. An asbestos shingle is made after a patent process. The size is usually 12″×12″×¼″. The variety of color is not great. They are a little more expensive than wood and asphalt, but are more durable.

Tin and galvanized shingles. Tin and galvanized iron are offered in plain shingles and various stamped shapes, in imitation of some of the older roofing tiles, but are comparatively short-lived.

Tile shingles. Roofing tiles, which are made of clay or concrete, are heavy and used only on the best of buildings where permanent construction is more important than low cost.

Slate shingles. Slate, which is to be had in several sizes and two or three thicknesses, is also too heavy and too expensive for most buildings. Tile and slate will weigh from 750 to 1000 pounds per hundred square feet laid on the roof.

Paper roofing. Among the cheap roof coverings is the paper roofing or rolled roofing. These come in weights designated as ½, 1, 2, 3 ply, and extra heavy. The widths are 18 and 36 inches. A roll contains enough roofing to cover 200 square feet, including the lap.

Tar-and-gravel roof. A tar-and-gravel roof is used on roof surfaces that are nearly flat. The expense is somewhat higher than that of rolled roofing, which may be used on flat surfaces, but the life of tar and gravel roofing is usually somewhat longer.

FINISHING

Plaster. Real plaster is usually made of sand to which are added hair or fiber and a cement in the form of Portland cement, natural cement, hydrated (water-slaked) lime, plaster of Paris in its natural state or as a patent plaster such as Keene cement. The oldest combination was lime, sand, cow's hair, and water. Later improvements are known as patent plasters. They differ largely from the old plaster in that they contain the necessary hair or fiber and a percentage of plaster of Paris which results in a hard wall surface. With the patent plaster the sand and the water are the only ingredients which must be added. Portland cement and natural cement plasters are mixed and tempered as in cement surfacing work. Keene cement is plaster of Paris which has been saturated with an alum solution, then burned and reground. It is hard and very impervious to water.

Substitutes. There are numerous commercial substitutes for plaster and for lath and plaster which may be used on temporary buildings or as an insulating course. They are manufactured from wood and paper used in combination; from wood fiber rolled into a thick sheet; from wood, asphalt, and paper in combination; and from plaster and paper in combination. Some are used as delivered; others must be covered with paint or paper, while some must be given a coat of regular plaster in order to have a permanent finish. There is little to be saved by the use of any of these wall coverings.

Paper. Paper is generally used as a protective and ornamental covering for plastered walls. It may be purchased in a great variety of patterns and grades and comes 18 inches in width and in single rolls of 23 lineal feet or double rolls of 46 feet. It is stuck to the wall by means of a flour-and-water paste. This paste is boiled to such a consistency that it will spread in an even thin coat, but not run or drip from the paper during the process of hanging.

Paint. Paint is a liquid protective covering for exposed surfaces. It is applied to all building materials, wood, steel, brick, or stone. In composition it is a base, a vehicle, and a solvent.

Bases. Lead carbonate or white lead, zinc oxide or zinc white, are the most common bases. Red lead, which is used for barn paint, is lead oxide which has been burned. Barium sulphate and zinc sulphide are used to some extent for interior work where the exposure is less than on outside surfaces. There is a number of mineral or metallic base substitutes which cheapen the product in both price and quality. The most common of these are: gypsum, or plaster of Paris; whiting, or chalk; ochre, a natural earth colored by iron oxide and zinc oxide. The last is not a cheap substitute and one which, if used in excess, produces a paint inferior to that made of white lead.

Vehicles. Linseed oil is the most extensively used vehicle. It is used both raw and boiled. It is produced from flaxseed through a process of grinding and pressing. Raw linseed oil is better than the boiled for mixing the first or priming coat, since the aim of this coat is to penetrate the wood as far as possible. The boiled oil dries by producing a film over the surface. This oxidizing of the surface is conducive to a strong and lasting paint surface. The raw oil is slow to oxidize. No real substitute has ever been found for linseed oil, although there are numerous substitutes on the market, some of which may be mixed with linseed oil in limited proportions without materially affecting the life and appearance of the paint. These are usually of animal or vegetable nature. The most common vegetable oils are hemp and cottonseed. Either is quite difficult to detect. Fish oil is used to some extent, and mineral oils when thinned with benzine.

Solvents. A solvent is added to a paint to give a lighter body or consistency. It is the intention that the solvent shall evaporate. It is possible, therefore, to use more solvent and produce a paint which will spread more easily, or which may be spread in a thinner coat. Turpentine is the best solvent known to the paint trade. It is a product distilled from the yellow pine tree. It is colorless and has a distinctive odor. It is adulterated by the use of mineral oils such as gasoline, benzine, and naphtha.

Driers. A drier is added to a paint to hasten oxidization of the surface, thereby producing a quicker setting and drying paint. The duty of the drier is to carry oxygen to the paint. Driers are usually compounds of lead and manganese, dissolved in oil, with which are used the standard solvents, such as turpentine or benzine. The quantity of drier should be limited to about 10 per cent, since too rapid drying will tend to produce a surface that will crack.

Colors. Coloring matter is to be had in several qualities, although in very few pure colors. Black is used in the form of lamp black, bone black, and graphite. The yellows are usually chromate of lead. The green known as chrome green is largely arsenate of copper. The blue known as Prussian blue is ferric-ferrocyanide. Red, violet, and purple are of coal-tar origin. The various shades and tints are obtained by mixtures of the above-named coloring pigments. Among the color substitutes the metallic oxides of iron, such as brown hematite, and brick dust are the most common. This latter differs very little from ochre, except in the degree of burning.

Paint for inside. Paints for inside work are usually more popular if free from gloss. This condition is easily obtained by the use of less oil and more turpentine in mixing for the proper consistency.

Ready-mixed paints. Ready-mixed paints are to be had in many varieties and prices. There is a large number of makes of ready-mixed paints which are reliable and will last as long as the "mixed-on-the-job" article. The mixed paints are expecially valuable for the floor and porch. It is usually desirable to have a floor paint which will dry quickly, but with an elastic surface.

Cold-water paints. Cold-water paints are a simple mixture of an adulterating base, such as whiting or gypsum, together with some cementing material, such as glue. They are mixed with water and applied in the same way as any other paint. They are inexpensive and not waterproof, but may give a hard and highly satisfactory surface for interior wall decoration.

Cement paint. Ordinary oil paints are not satisfactory when applied to a concrete surface. The excess of alkali in the cement must be neutralized in some measure. The general practice is to use a special cement paint. It is characterized by the addition of zinc sulphate or an equivalent. If the ordinary paint is to be used, it is necessary first to wash the surface with a solution of zinc sulphate, which should be followed by a clear water washing and allowed to dry thoroughly. The market offers solutions for cement floor treatment which are, in fact, only hardeners. They are very effective and comparatively cheap, since a large percentage of the hardener is water.

Creosote. This protective solution is made of creosote oil with the addition of a pigment to give it color. Creosote is the result of tar distillation. It is highly preservative and, being thin, penetrates a surface such as wood or fiber.

Stains. Stains are of four varieties: oil, water, spirit, and acid. A stain is not intended to be a covering. It is applied to change the appearance of a surface. *Oil stains* usually contain very little of the vehicle oils; they are very largely the solvent and drier oils, with the addition of sufficient pigment to give the desired tone. *Water stains* are similar in make-up and application, except that water is the solvent and carrier. The water stains have the unfortunate peculiarity of roughening or raising the grain of the wood, making it necessary again to rub the surface in order that it may be finished smooth. *Spirit stains* are practically the same as water stains, except that alcohol is used instead of water. They are a little more penetrating and give better results on very hard wood. *Acid stains* are more penetrating than any of the others, since their solvent and carrier is acid. Little, if any, pigment is necessary with an acid stain. The acid, itself, attacks and colors the surface of the wood. It is usually necessary to add a neutralizing agent, such as ammonia, in order that no surplus acid be left on the surface. It would be difficult to apply any finish over the acid-stained wood if there still remained any free acid.

Varnishes. Varnishes are classed as spirit and as oil varnishes. The spirit varnish is also known as *shellac.* It is a lacquer made by dissolving in alcohol the shell or scale of a family of insects which live on the bark of certain trees. This shell is brownish in color and very resinous. When dissolved in its native state, it is known as brown or orange shellac; when bleached, it is white shellac. It gives a very hard and brittle finish. Its chief use is to seal the pores of open-grained woods, where it is desired to finish a natural color or with but a slight stain. It dries rapidly and is a little difficult to apply without leaving laps which show after the work is finished. The *oil varnish* is made by dissolving in linseed oil some of the resinous gums such as copal, amber, and anime. The copal is the cheapest and by far the most extensively used. The best varnishes are slow in drying. Soft gums, such as sanderad, make a quick-drying, but a softer and less permanent varnish, which is short-lived when exposed. Another class of varnish is made by dissolving some of the better gums in well-aged turpentine. This produces an intermediate grade of varnish.

Wax. Wax is used for interior finishing work, especially upon floors. It is known on the market as prepared wax. It is in a pastelike form, and when allowed to set may be polished and produce a highly satisfactory, though not so permanent a finish as varnish. Wax may also be had in dry form, such as is used on dance floors.

Whitewash. The Lighthouse Board of the United States Treasury Department uses the following mixture: ½ bushel lime slaked in boiling water. Keep covered while slaking. Strain and add 1 peck of salt, dissolved in warm water, 3 pounds of ground rice, boiled to a thin paste, ½ pound powdered Spanish whiting, and a pound of clear glue, dissolved in warm water. Mix well, allow to stand for several days, and apply as hot as possible. A whitewash which serves very well for inside work is made of one part (by volume) of unslaked lime, to 3 parts water, stirred while boiling. It is improved by substituting for half of the water skimmed milk or buttermilk. To be applied cold.

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PART III. LAND IMPROVEMENT

CHAPTER X

EXPLOSIVES

KINDS AND METHODS OF USING

An *explosive* is a substance which can be suddenly changed to a gas many times its original volume. A material that burns under ordinary circumstances is *combustible*. The finer the particles into which a combustible material is divided and the more thoroughly mixed with air, the more rapidly it will burn. Wood in a large stick is difficult to set on fire. The same stick split into small kindling will burn fairly easily. If cut into shavings, it ignites with a spark. When ground into fine dust and suspended in the air, it burns with explosive rapidity. An explosion of sawdust in a Philadelphia box factory caused the death of one man and injured five others. The explosion was produced by the contact of a cutter and a broken bolt, which generated a spark, and this in turn ignited the sawdust particles in the air. Serious explosions have occurred in corn-product mills, candy factories, spice mills, linoleum factories, malted-milk plants, and coal mines owing to the ignition of the dust created during the processes of manufacture. It has been estimated that a 25-pound sack of flour mixed with 4,000 cubic feet of air will, if ignited, generate enough force to throw a ton of iron one mile. Marsh gas, coal gas, acetylene, and gasoline vapor, when mixed with air, burn so rapidly that the burning takes the form of an explosion.

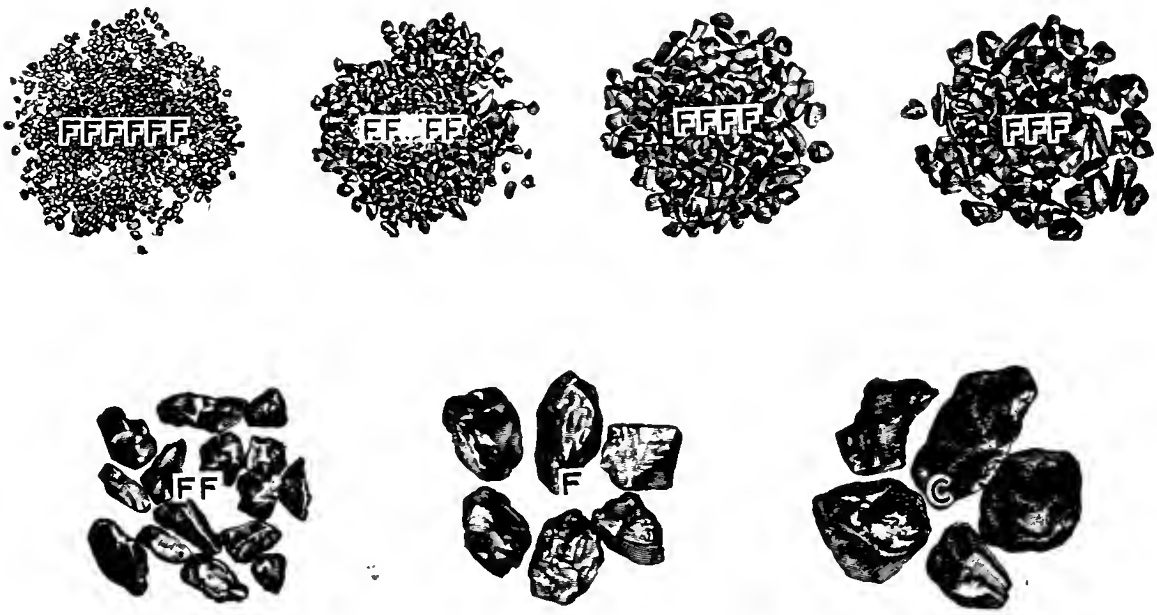
Oxygen in the air produces combustion; when the oxygen is separated from the air and brought into contact with burning bodies, the combustion is more rapid and complete. Oxygen occurs in nature in many forms, one of these being saltpeter (niter or potassium nitrate). When saltpeter is thoroughly mixed with a combustible substance such as charcoal, the mixture will burn without being in direct contact with the air, producing a gas which expands very rapidly. An explosive prepared in this way is ordinarily termed gunpowder. Oxygen may be obtained from saltpeter heated properly with sulphuric acid, the resulting product being nitric acid, which contains all the original oxygen of the saltpeter. Such substances as cotton, starch, and glycerin are converted by the action of nitric acid into high explosives much more powerful than gunpowder and are known as guncotton, nitrocellulose, and nitroglycerin. Nitric acid treated with alcohol will dissolve such metals as silver and mercury, forming compounds still more violent and sensitive in their explosive effects. The commercial product of this process is fulminate of mercury.

As to effect, explosives may be divided into two classes: slow or *propulsive*, such as gunpowder, which generate pressure comparatively slowly; high or *disruptive*, such as nitroglycerin or fulminate of mercury, which generate pressure instantaneously. Propulsive explosives are of value in firearms, quarry work, and occupations in which the intention is to move material rather gradually and not tear it to pieces. Disruptive explosives can be used only where the intention is to destroy and shatter.

Gunpowder. A mixture of charcoal and saltpeter alone is not easily fired. The addition of sulphur greatly facilitates ignition. A combination of seventy-five parts saltpeter, fifteen parts charcoal, and ten parts sulphur, finely ground, is *gunpowder*, the simplest and most common commercial explosive. Gunpowder was invented about the year 1250. Credit for its invention has been given to Bertholdt Swartz, a German monk, and also to Roger Bacon of England. Some are of the opinion that it originated in China. Its first use as a propelling agent has been ascribed to the Moors and Saracens in the fourteenth century.

It was manufactured in France and England as early as 1338. In 1858 Lamotte du Pont, of Wilmington, Delaware, invented *blasting powder* (Fig. 155), which differs from gunpowder in that Chile saltpeter (sodium nitrate) is used in the place of India saltpeter (potassium nitrate).

Gunpowder ingredients are ground to a powder separately, then ground together with a little water until completely mixed. The material is then formed into cakes, after which it is broken up into grains and dried. It is glazed by rubbing and sorted into sizes by sieves. The object of the glazing is to prevent the grains from absorbing moisture from the air and to cause them to be free-running so they will fit more closely together.



After E. I. du Pont de Nemours & Co.

FIG. 155. *Various sizes of Du Pont "A" blasting powder*

Nitroglycerin. Nitroglycerin was first made in Paris in 1846 from glycerin treated with strong nitric and sulphuric acids. The ordinary process of manufacture consists of mixing five parts sulphuric acid, three parts nitric acid, and one part glycerin in a lead vessel. The acids are placed in the vessel and the glycerin added in a small stream, the temperature being kept below 85° Fahrenheit by an air blast. The nitroglycerin settles and the spent acid is poured off, after which the nitroglycerin is filtered and washed. It is a colorless liquid which dissolves very slowly in water. Nitroglycerin is sweet in taste and poisonous. Medically it is used as a heart stimulant, but its greatest value is in the manufacture of commercial dynamite.

Fulminate of mercury. Fulminate of mercury is a gray crystalline salt formed by the action of alcohol and nitric acid on mercury nitrate. When dry this compound can be exploded by a very slight blow or rise in temperature. It is too sensitive to be used as a primary commercial explosive, but the ease with which it can be fired makes it valuable for use in very small quantities as a detonator for other explosives.

Dynamite. Dynamite is the explosive most frequently used for blasting. It was invented by a Swedish chemist named Noble in 1867. The object of its invention was to overcome the disadvantages of nitroglycerin due to the danger in storing and transporting. Dynamite provides for the use of nitrogylcerin in a form which is comparatively safe and convenient. It is made by the absorption of nitroglycerin in some porous substance called the *base*. Three kinds of material are used for the base: An *inert base*, one composed of an absorbing material which is itself neither combustible nor explosive and serves only as storage for the nitroglycerin; a *combustible base*, one composed of an absorbing material which is combustible and adds to the explosion the force generated by combustion; an *explosive base*, one composed of material which is itself an explosive and on the explosion of the nitroglycerin explodes with it. The term *active base* is applied to both the combustible and the explosive. Practically all dynamite of the present day has an active base.

Good dynamite has much the consistency of dark-brown sugar. It varies in color, being brown, gray, white, yellow, or red, according to the base used. It appears on the market in cylinders, usually 8 inches long and from ⅞ to

1¼ inches in diameter, each stick weighing half a pound. Each cylinder is wrapped in paraffin paper to keep out moisture and packed in boxes holding from five to one hundred. Dynamite is manufactured in many strengths or grades directly dependent upon the percentage of nitroglycerin present, which varies by steps of 5 per cent from 20 to 70. The smaller the nitroglycerin content, the slower and less shattering the explosion. Grades varying from 25 to 40 per cent are the ones best adapted to work on the farm.

After E. I. du Pont de Nemours & Co.

FIG. 156. *Stick of dynamite*

Dynamite may be fired by a severe concussion or blow, its sensitiveness increasing with the temperature. When brought close to a flame in the open air it will take fire at 356° Fahrenheit and burn slowly, but if confined it may be exploded by a red-hot iron or by being heated to a high temperature. While dynamite can be safely handled at ordinary temperature, it decomposes when exposed to the direct rays of the sun, and it is dangerous to allow the sun to shine upon it through a window. In water the nitroglycerin separates from the base, and for that reason in wet places it should be fired within one-half hour after being placed. The absorption of moisture decreases its strength, 15 per cent being sufficient to prevent explosion. It freezes at a temperature of 42° to 50° Fahrenheit.

Advantages of dynamite. For use on the farm dynamite has many advantages over black powder. It is in more convenient form, produces better results, is safer, and permits greater economy of time and labor. Since it is manufactured in so many grades, one can be found suitable for practically any class of work in hand. It can be used under conditions of moisture which would make black powder worthless. Powder does not give results unless it is thoroughly tamped, and this necessarily means the drilling or boring of holes. Frequently a grade of dynamite can be selected that will give results without tamping. Dynamite may be stored and transported with comparative safety, and sparks will not ignite it.

Special explosives. Explosives are on the market under various trade names. They differ somewhat in their chemical composition from ordinary dynamite, some small percentage of the ingredients being known only to the manufacturer of each brand, but they accomplish practically the same results and are handled in the same manner as described for dynamite.

The charge. In practical blasting the quantity of explosive assembled in one complete unit is known as the charge. This consists of the explosive proper with a suitable primer for firing. The method of making up a charge is determined by the nature of the explosive used: gunpowder is fired by a spark, dynamite by detonation, nitroglycerin by concussion.

Safety fuse. A safety fuse (Fig. 157) is a core of very fine gunpowder surrounded by yarn and lapped with tape. The tape is waterproof and is dusted with powdered soapstone to prevent stickiness. The fuse may be single, double, or triple tape, according to the amount of moisture resistance required. Cheap hemp or cotton fuse is made for work which is dry, and gutta-percha fuse for work which is submerged. A single or double tape fuse is most satisfactory for ordinary farm purposes. The object of the fuse is to carry a spark of fire directly into a black powder charge or into the detonator when dynamite is used. The powder core at the outer end of the fuse is lit with a match and burns at a rate of 3 feet per minute. Safety fuse is placed on the market in 50-foot coils, two coils in a package.

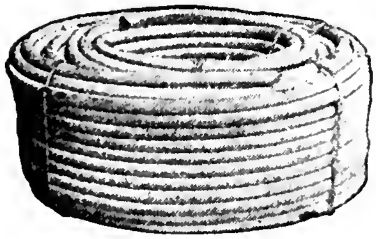


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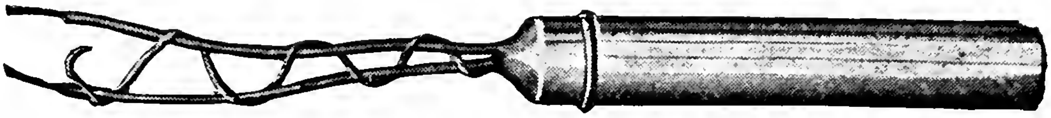
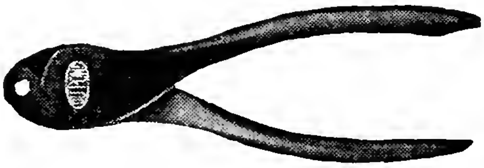
FIG. 157. *Coil of safety fuse*

Detonator. The detonator or cap is a tube of copper containing a small quantity of fulminate of mercury which is exploded either by a spark of fire applied to a safety fuse or by a wire heated by an electric current. This explosion fires the enveloping charge of dynamite. Caps are sold on the market in boxes of one hundred, under the name of single, double, triple, or quadruple strength according to the quantity of fulminate of mercury contained. The appearance of the cap fired by electric current differs from that fired by the safety fuse in that a pair of electric wires 3 feet long are attached (Fig. 158).


After E. I. du Pont de Nemours & Co.
FIG. 158. *Electric fuse*

Preparing the charge. If a safety fuse is to be used, one end is cut square and carefully inserted into a cap. It should be gently pushed straight into the cap until it fits against the cap filling. Hard pressure, twisting, or turning of the fuse must be avoided. The open end of the cap should then be fastened to the fuse with a *crimper* (Fig. 159), a small pincer-shaped instrument made for cutting fuse and binding the end of the cap around it. With a small piece of hard wood or a lead pencil, a hole should be made in the center of the top end of the dynamite stick, the cap to which the fuse has been attached inserted in this hole nearly its full length, the dynamite pressed around the outside of the cap, and the fuse tied to the stick with a string. This combination of the fuse, cap, and one stick of dynamite is generally known as the *primer* and is ready to be exploded when the outer end of the fuse is lighted. If one stick of dynamite is sufficient for the charge, it can


After E. I. du Pont de Nemours & Co.
FIG. 159. *Cap crimper and fuse cutter, one handle of which will serve to make the cap opening in the stick of dynamite*

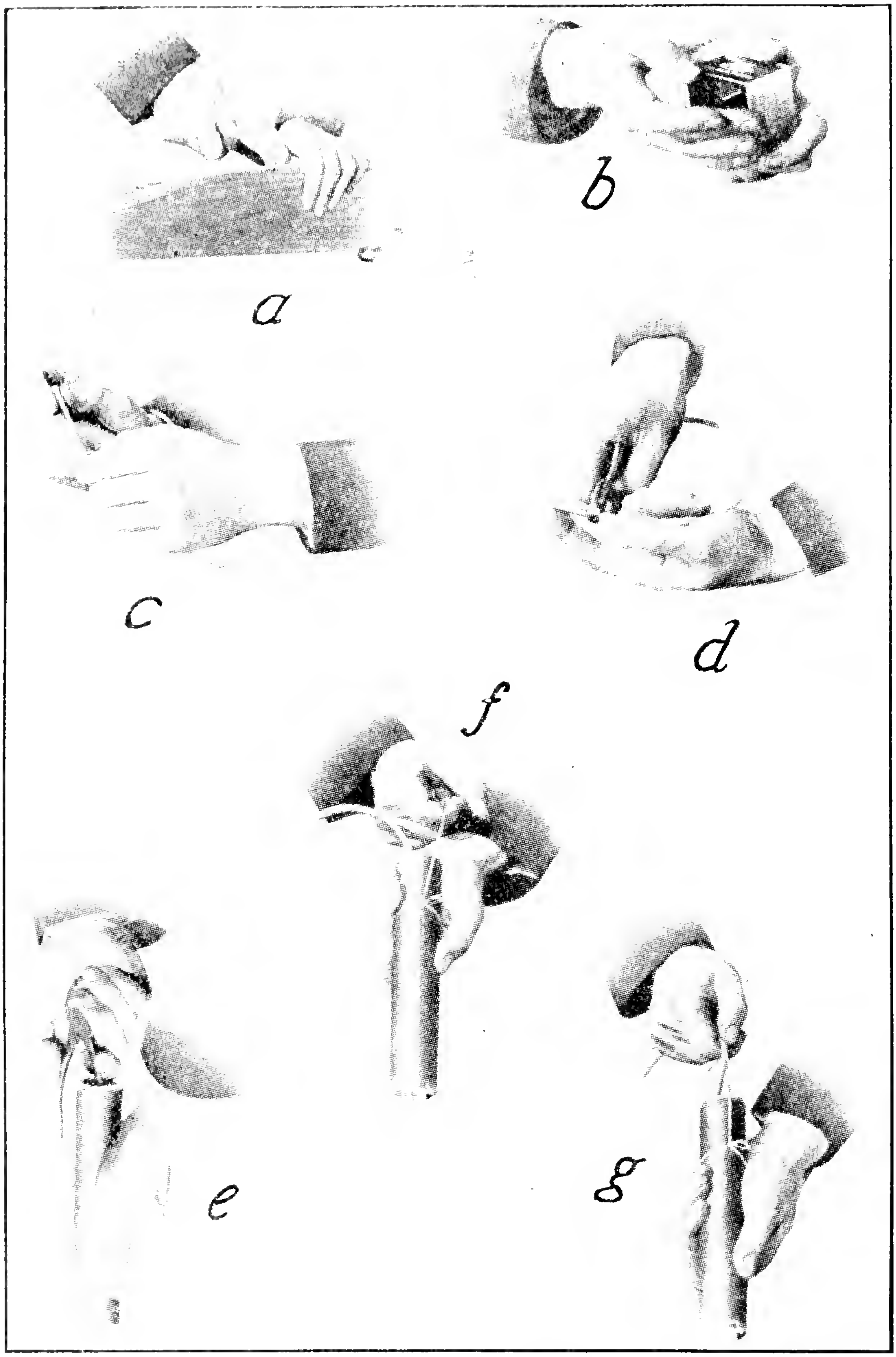


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FIG. 160. *Preparing primer for safety-fuse firing when drill hole is small*

(*a*) Cut off sufficient length of the fuse. (*b*) Take one cap from the box with the fingers. (*c*) Place cap on end of fuse. (*d*) Crimp cap to fuse with cap crimper. (*e*) Punch a hole in end of cartridge with handle of cap crimper. (*f*) Tie cord around cartridge. (*g*) Tie cord around fuse.

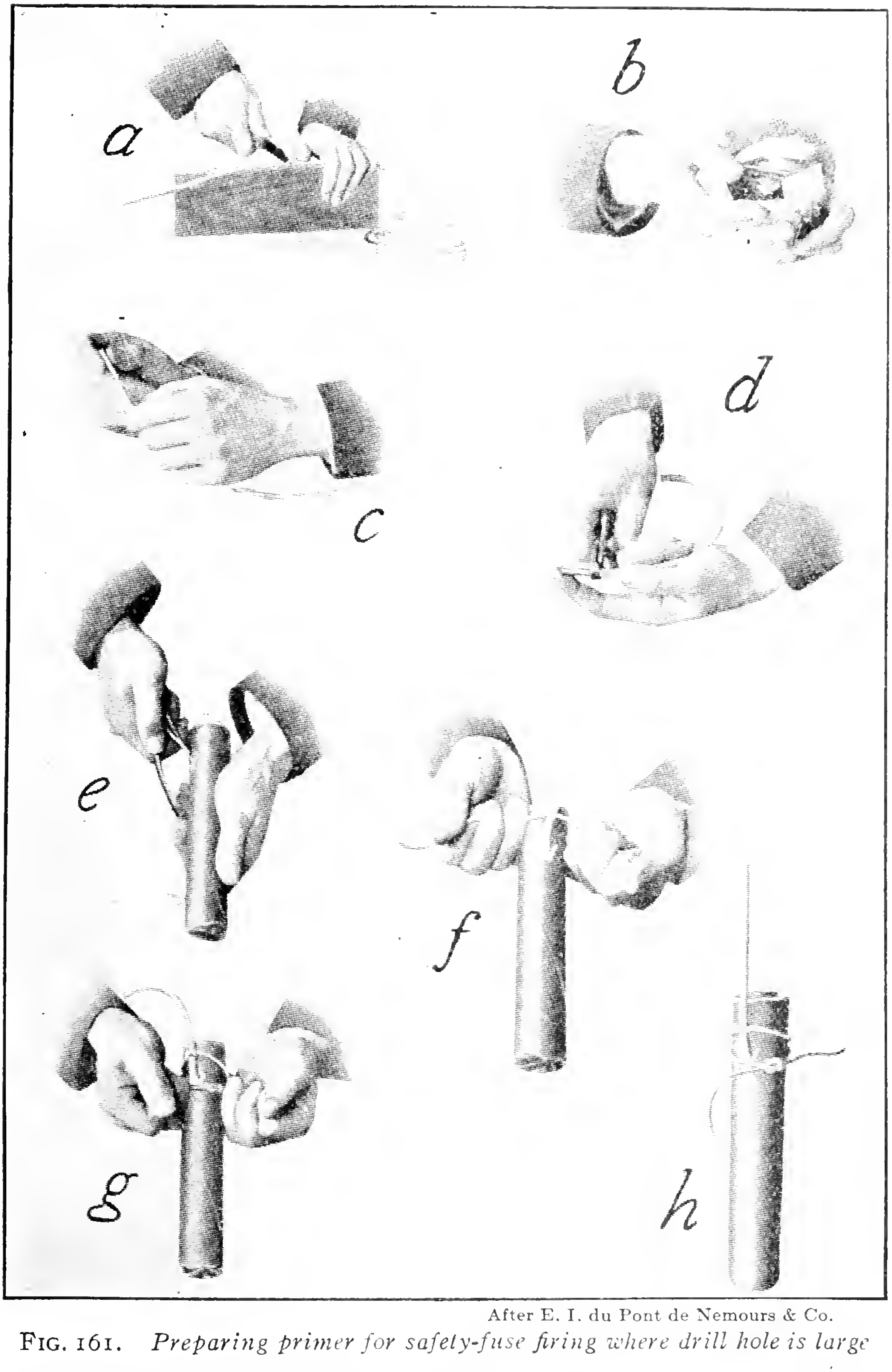

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FIG. 161. *Preparing primer for safety-fuse firing where drill hole is large*

(*a*) Cut off sufficient length of fuse. (*b*) Take one cap from the box with the fingers. (*c*) Place cap on end of fuse. (*d*) Crimp cap to fuse with cap crimper. (*e*) Punch hole in side of cartridge with handle of cap crimper. (*f*) Tie cord around fuse. (*g*) Complete by tying cord around cartridge. (*h*) Completed primer ready to be loaded.

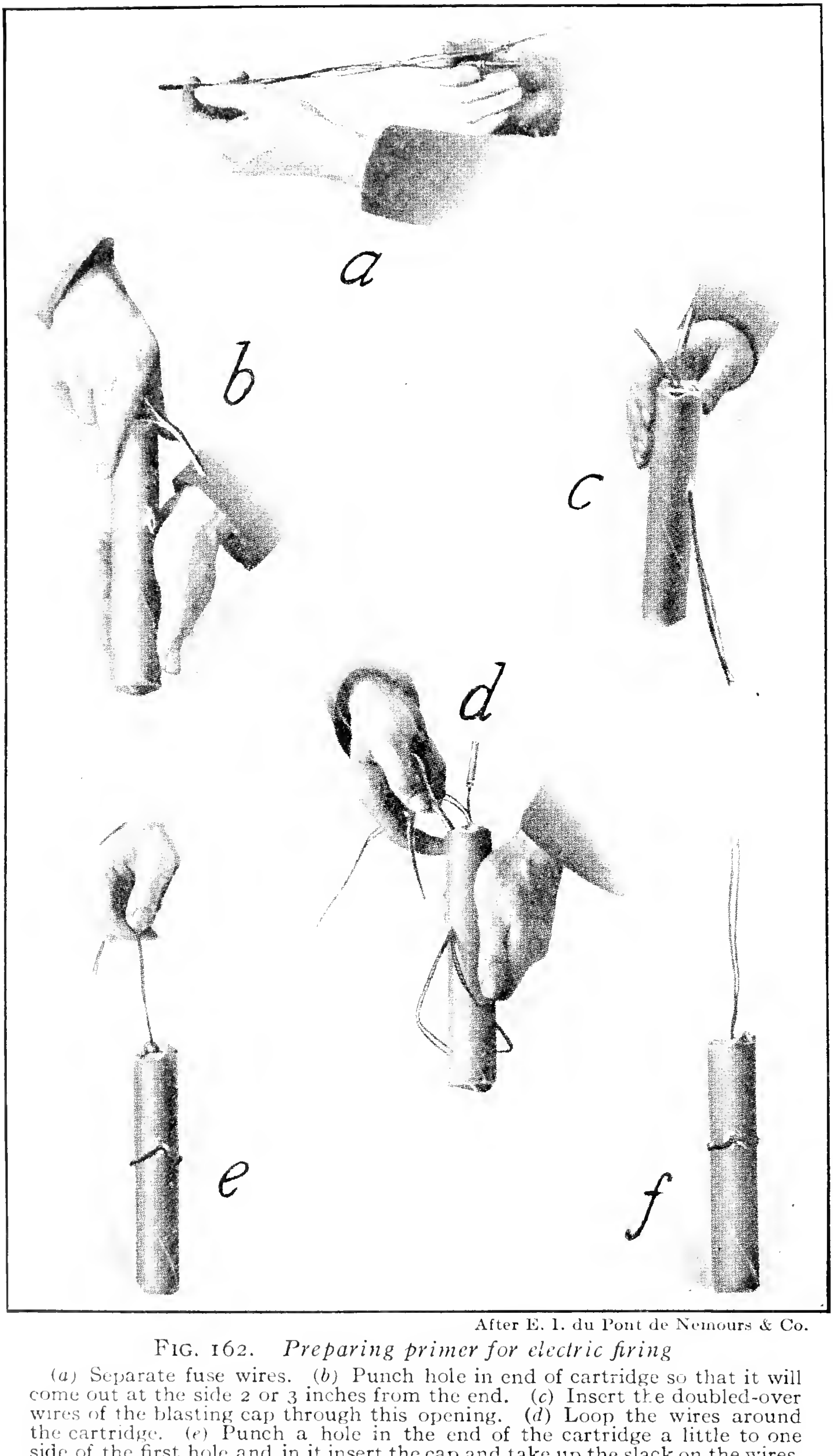

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FIG. 162. *Preparing primer for electric firing*

(*a*) Separate fuse wires. (*b*) Punch hole in end of cartridge so that it will come out at the side 2 or 3 inches from the end. (*c*) Insert the doubled-over wires of the blasting cap through this opening. (*d*) Loop the wires around the cartridge. (*e*) Punch a hole in the end of the cartridge a little to one side of the first hole and in it insert the cap and take up the slack on the wires. (*f*) Electric primer ready for firing.

then be inserted in the hole or other place prepared. If one stick is not sufficient, other sticks can be placed around the primer, or, if it is in a dry place, the paper wrappings of the other sticks can be slit along one side and they can then be packed into the hole and the primer placed along the side or on top of the loose dynamite, the entire charge being fired by one primer. The charge for electric firing is prepared as described in Figure 162.

Placing the charge. The location of the charge to accomplish the desired results will depend upon the nature of the material to be moved. It should be pressed down into the hole with a wooden rod, care being taken not to break the firing connection of the primer. The hole may be tamped with clay, loam, or sand, and sometimes paper or other visible material is placed 4 or 5 inches above the top of the primer to locate the charge in case of misfire when it becomes necessary to place a second primer. This requires time and is probably not advisable unless there are reasons for expecting a misfire. Hard tamping should not be resorted to until the primer has been covered 5 inches. The more tightly and firmly the charge can be put in place, the more satisfactory the results will be and the less explosive will be required. The fuse should be long enough to reach 6 inches above the tamping and to give the operator ample opportunity to reach a place of safety before the explosion occurs. (See Fig. 163.)

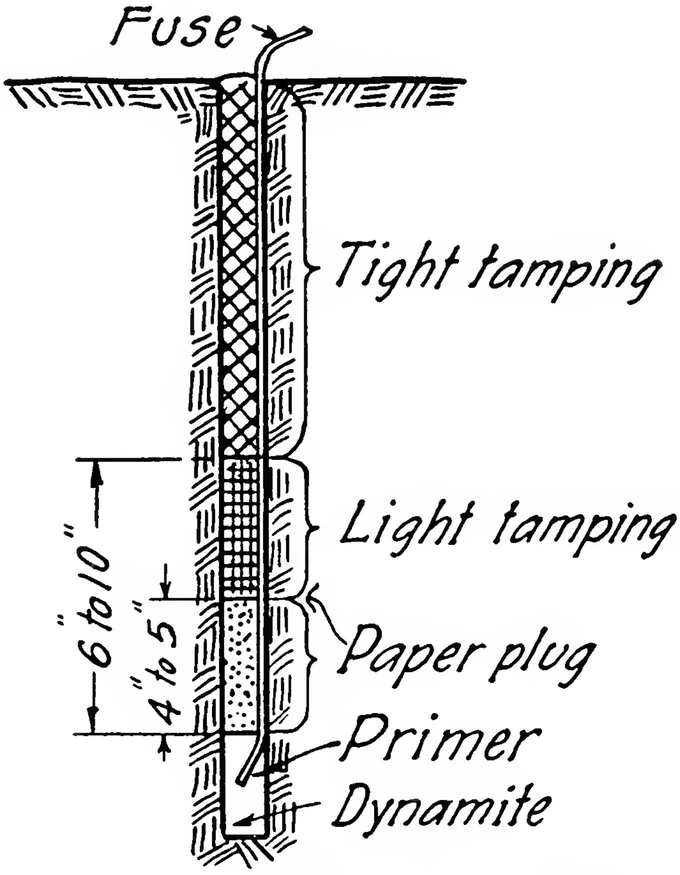

FIG. 163. *A charge ready for firing*

Firing the charge. Before an attempt is made to light a safety fuse, a split of three-quarters of an inch should be made with a knife and the match held in such a way that

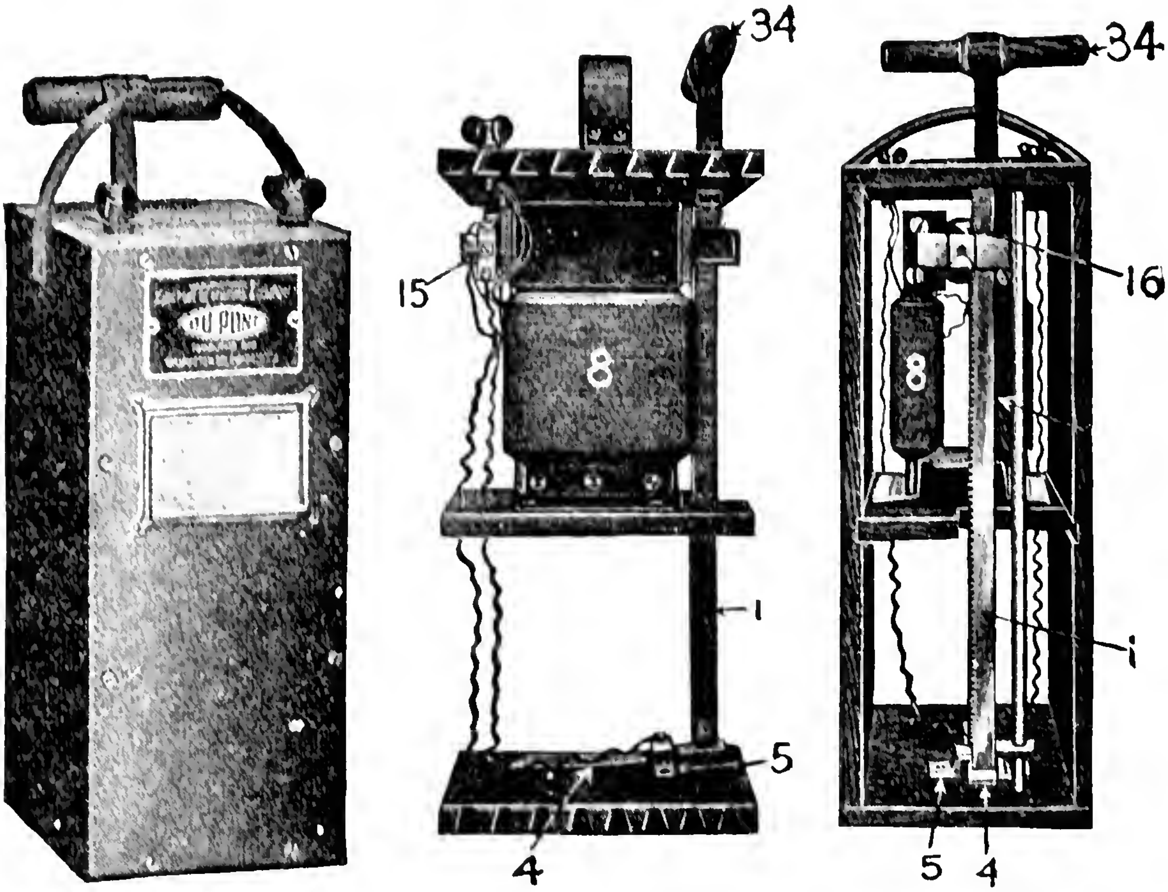

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FIG. 164. *Two-post blasting machine*

1—Rack bar 4—Shunt spring 5—Platinum bearings 8—Principal magnet 15—Commutator 16—Armature 34—Handle bar

the blaze strikes the freshly exposed powder. At the time the fuse is lighted it should be watched until there is a certainty that the powder core is burning. This may be ascertained by the smoke, the hissing sound, or the melting of the waterproof wrapping. Persons unaccustomed to the use of a fuse should familiarize themselves with it by burning several short sections before undertaking to fire a charge.

For electric firing a blasting machine is used, which is simply a small magneto incased in wood (Fig. 164). These machines differ in strength, the smallest one firing eight caps at a time on one circuit. Insulated wire extends from the machine to the charge, being of sufficient length to enable the operator to stand at a place of safety at the time of firing.

Since the wire near the point of explosion is broken and destroyed at each firing, a section of cheap insulated wire is used to connect the main lead wires with the fuse wires. In conecting up the circuit the insulation at the end of the wire should be scraped back and the wires securely twisted together. In wet grass or on wet ground the connection should be wrapped with insulation tape; in dry work a small piece of wood laid under the wire at this point will frequently serve to prevent short-circuiting. The connection with the lead wire should not be made until all is ready for firing. The circuit can then be completed by the operator at the machine. As soon as the shot has been fired, the machine should be disconnected and remain so until the next shot is ready for firing.

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Fig. 165. *Coil of leading wire to carry from the blasting machine to the charge*

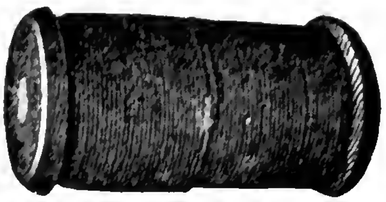

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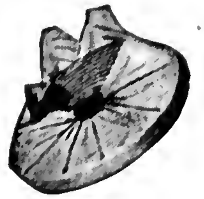
Fig. 166. *Spool of connecting wire to connect the fuse to the circuit*

Electric firing is generally considered safer and less liable to misfire than the safety fuse. It has an added advantage in that a number of shots may be fired at the same instant. In hard blasting a number of charges fired at one time will give much better results and require less explosive than if the shots occur at intervals.



After E. I. du Pont de Nemours & Co.

Fig. 167. *Coil of insulating tape to cover bare joints in wet work*

Misfire. Where a safety fuse is used, misfire may be due to one of the following causes: frozen dynamite, poor fuse, fuse slipped out of the cap, wet cap, or cap pulled out of the primer. When a safety fuse fails to burn, the source of trouble may be a space in the core where there is no powder. The fuse is likely to smolder along until the powder core is again ignited and a delayed explosion results. In electric firing misfire may be due to frozen dynamite, grounding of the circuit, short circuit, or the breaking of the platinum bridge of the cap by rough handling. In case of failure in electric firing the first step would be to disconnect from the fuse wires and test the electric circuit. Where necessary to use a new primer the tamping may be removed down to within 3 or 4 inches of the charge and another placed, tamped, and fired. Both charges will explode unless the dynamite is frozen.

Frozen dynamite. Dynamite freezes at from 42° to 50° Fahrenheit and should not be used when in this condition. It is hard to detonate and ordinarily does not have its full strength. When frozen, the sticks are hard and rigid. If properly thawed the explosive is not injured by the freezing, but where large quantities of dynamite are to be used provision should be made to keep it where it will not freeze, or it should be used before it has time to freeze. When it is necessary to thaw dynamite, it should be placed in a water-tight vessel set in another vessel containing warm water. The water in the vessel should be a few degrees above the freezing point of the dynamite, but not at the boiling point. Sticks of dynamite can also be thawed by being laid on a shelf in a warm room over night. Under no conditions should it be placed in hot water, in steam, in an oven, or before an open fire. Frozen dynamite is

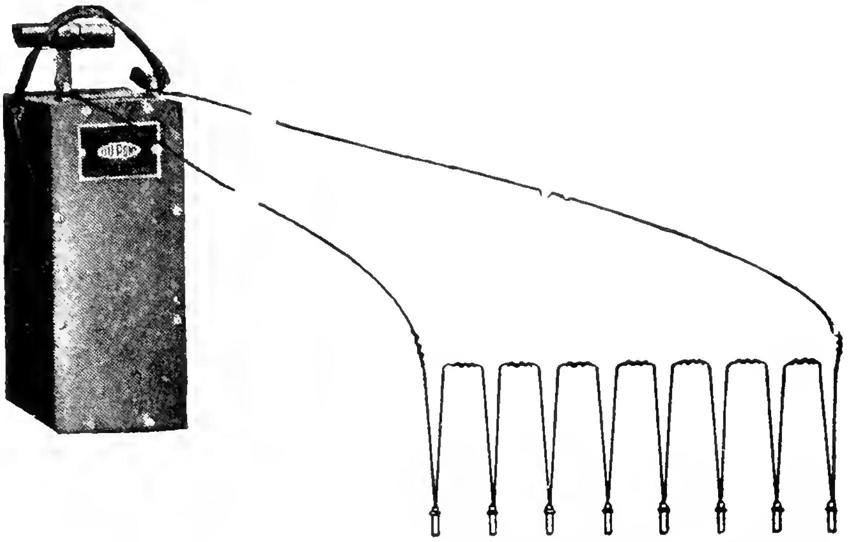


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FIG. 168. *Electric firing connected in series*

not sensitive to blows but is peculiarly sensitive to friction and should not be cut or broken.

PRECAUTIONS

1. Do not go near the charge for at least one-half hour if it fails to explode.
2. Do not dig out a misfire.
3. Use only a hardwood tamper.
4. Handle caps carefully. Do not drop them or lay them on the ground where they may be stepped on.
5. Do not use frozen dynamite.
6. Handle the sticks carefully, for when the cover is torn the dynamite is exposed to the moisture in the air.
7. Do not drop or throw dynamite.
8. Do not leave dynamite or caps exposed to the rays of the sun.
9. Store dynamite so that the sticks lie on the side, preventing dangerous concentration of nitroglycerin in the lower end.
10. Do not keep or carry caps with dynamite.
11. In crimping, great care must be exercised not to pinch the part of the cap containing the fulminate of mercury. There is sufficient explosive in the cap to injure a hand seriously. Never crimp with the teeth.
12. Do not tamp hard when near the charge.
13. To avoid headaches, do not inhale the fumes from a recent explosion and do not handle the dynamite without gloves.
14. See that all sticks in one hole are in contact.
15. Keep the dynamite and caps out of reach of stock. Cattle like the taste of dynamite because of the salty ingredient, but a very little proves fatal.
16. In electric blasting always make wire connections from the charge toward the machine, attaching the wires to the binding posts only when all persons are at a safe distance.

17. Thaw frozen dynamite slowly and use a thawing can with warm water. Never thaw in an oven or near an open fire.

USE OF DYNAMITE ON THE FARM

Stumps. In general, dynamite has been found to be the best agent for the removal of stumps because it not only loosens them from the ground, but breaks them up, frees them from earth, and makes them comparatively easy to pile and burn. For blowing a stump with taproot, the best results can be secured by the method of boring into the root and placing a charge near its center (Fig. 169). A small stump in fairly solid ground may be removed by a charge placed directly under the center. A large

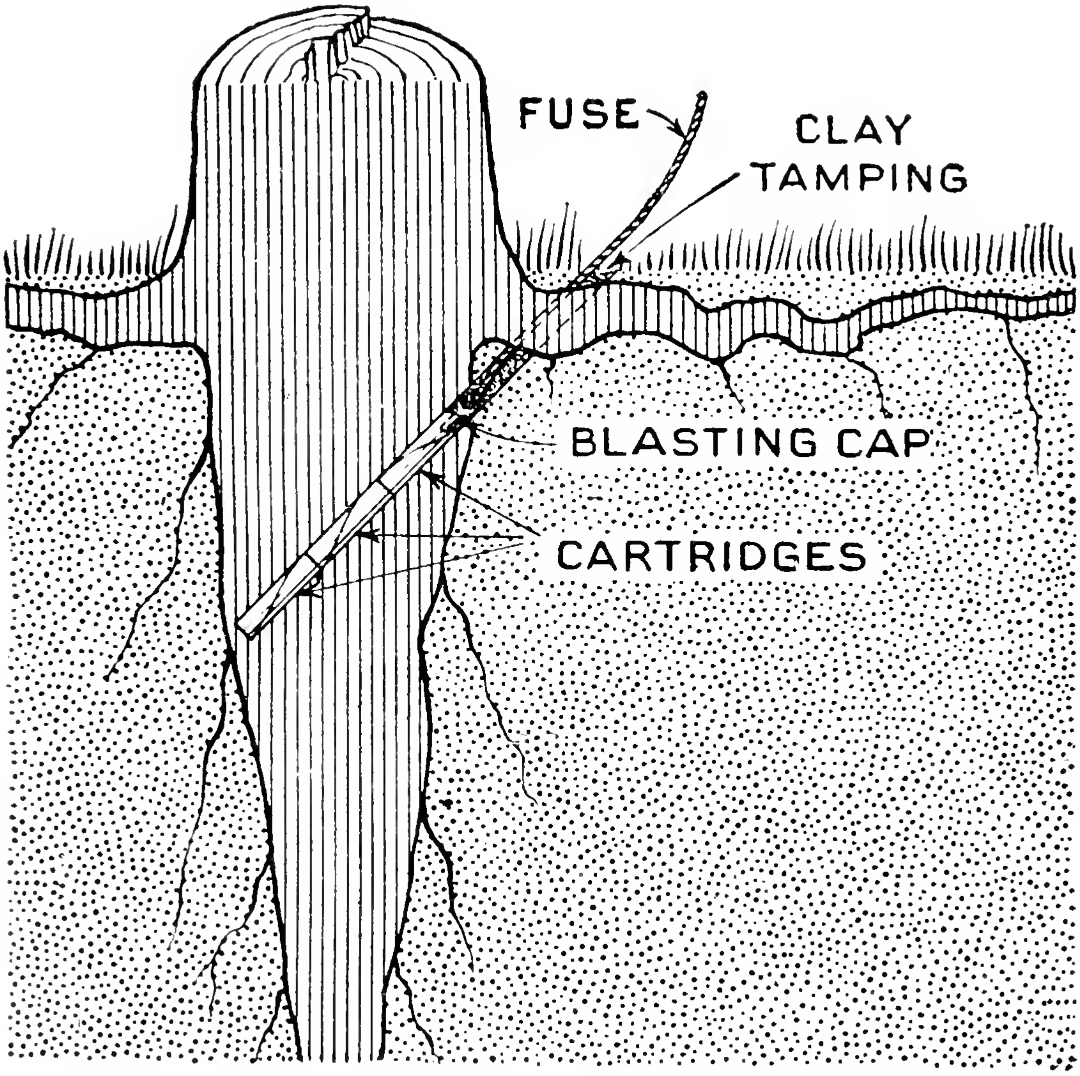

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Fig. 169. *Placing the charge in stump with tap root*

stump with strong lateral roots can be taken out with less explosive if a charge is placed immediately under each root and fired simultaneously with a machine (Fig. 170). The condition of the soil has considerable bearing on the grade and quantity of explosive to be used and the position of the charge.

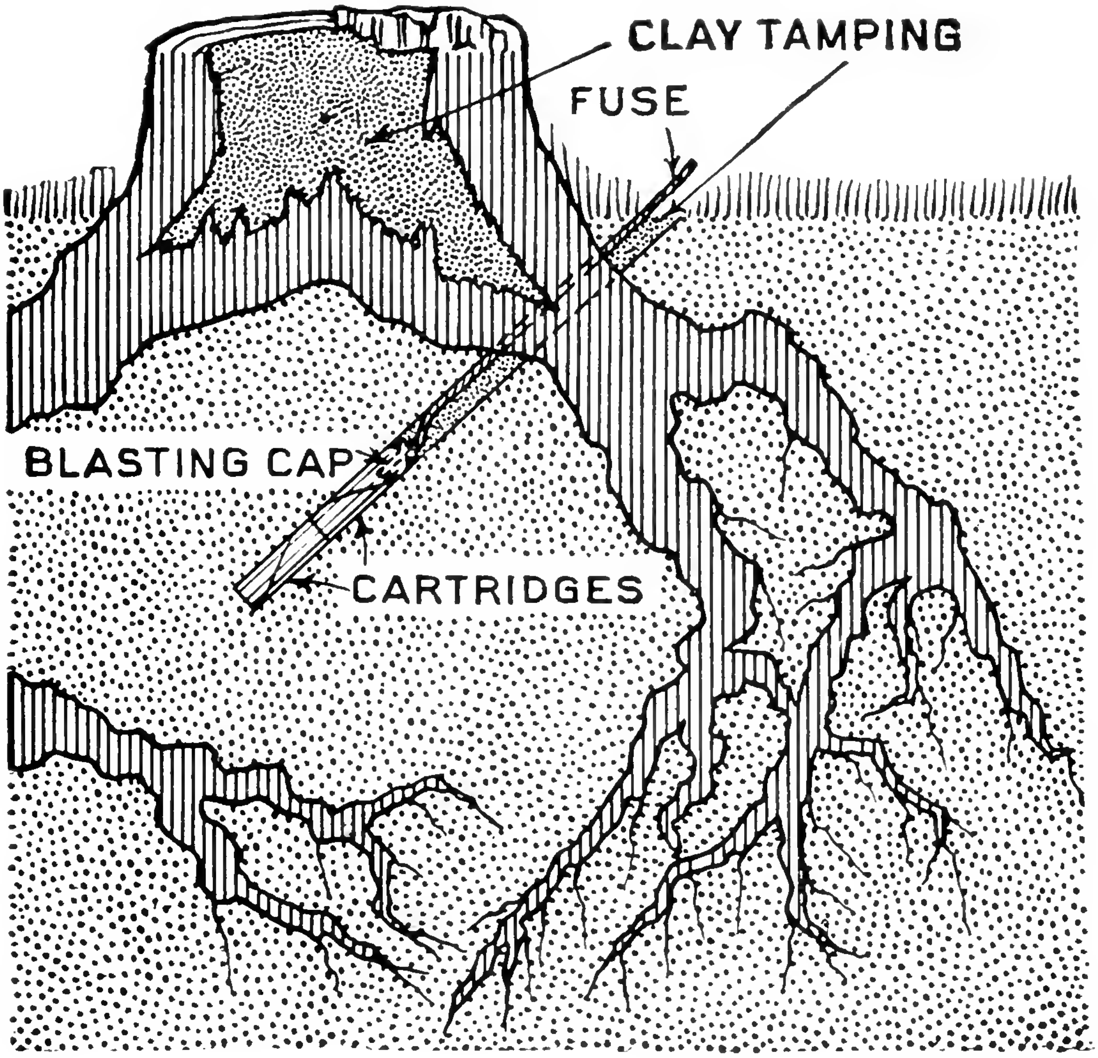

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FIG. 170. *Placing the charge in stump with lateral roots*

Bowlders. For breaking bowlders three methods are used in the placing of charges. One is known as *mud-capping*, in which the charge is placed in some depression on top of the bowlder and covered with mud. The second is called *snake-holing*, in which the charge is placed in a hole bored under the bowlder. In the third method, or *block-holing*, a hole is drilled into the bowlder and the charge placed near the center. The results obtained from

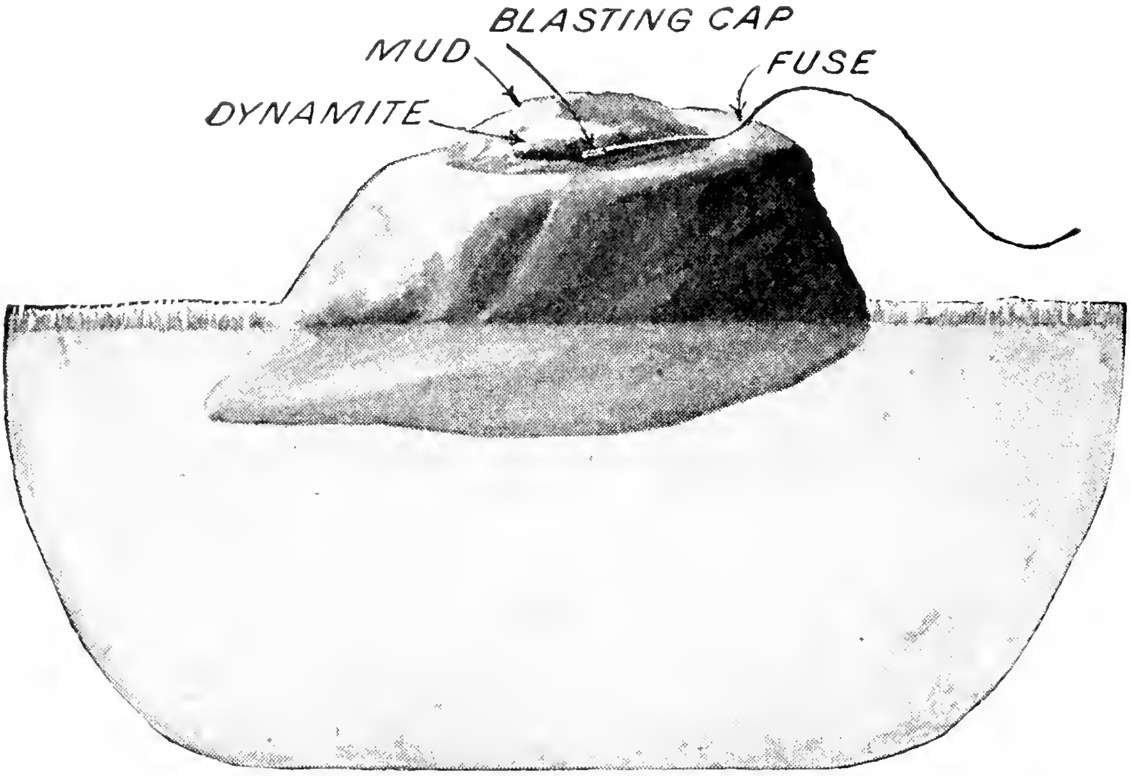

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FIG. 171. *Breaking bowlder by mud-capping*

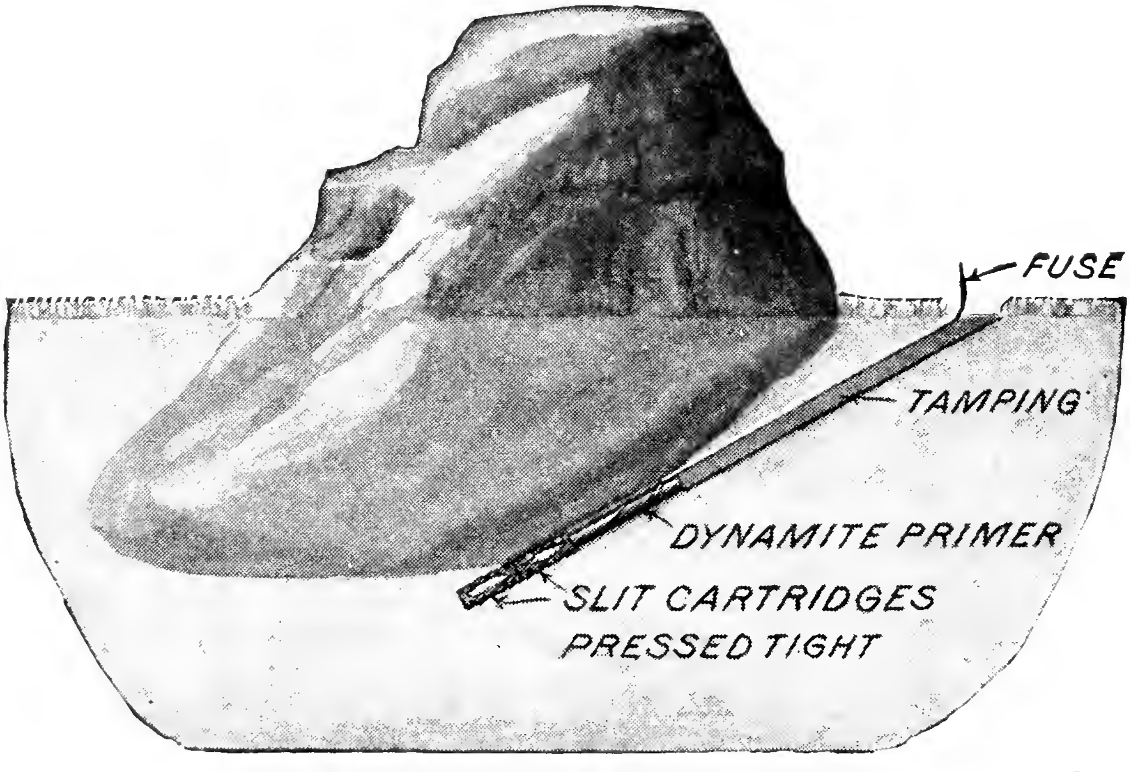

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FIG. 172. *Breaking bowlder by snake-holing*

these three methods depend upon the hardness and solidity of the rock and upon the relation between the cost of labor and the cost of the explosive. Mud-capping (Fig. 171) requires a small amount of labor but a large quantity of high-grade explosive, and with extremely hard bowlders satisfactory results are not obtained. Snake-holing takes more labor but less explosive and generally gives satisfactory results (Fig. 172). Block-holing requires a great amount of labor, but good results can be had in all classes of rock with a minimum of explosive (Fig. 173). Unless the nature of the rock in the locality is well known, experimental work should be done to determine which of these three ways is the most economical.

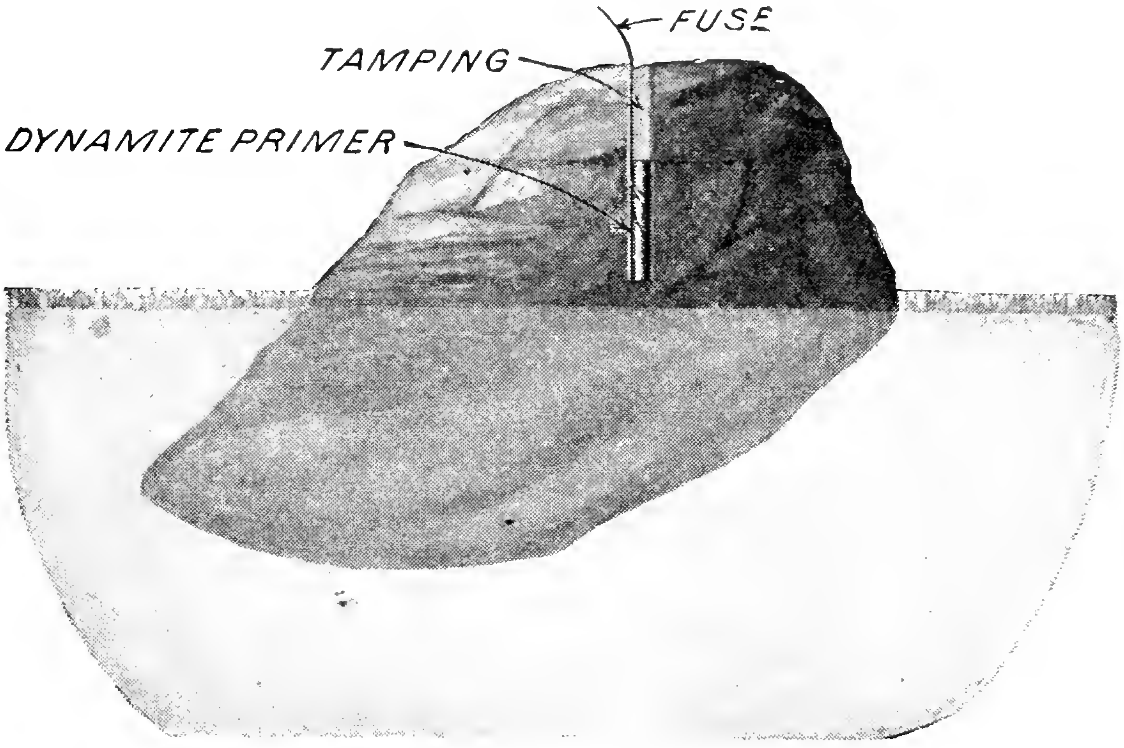

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FIG. 173. *Breaking bowlder by block-holing*

Hardpan. A stratum of hardpan located near the surface may be broken up by the explosion of light charges of dynamite at uniform intervals over the area. Holes should be bored into the hardpan with an auger, and a small charge of dynamite tamped in and exploded with a safety fuse. The depth of the charge and the quantity of explosive needed should be determined by experiment. A low grade, 20 per cent, is ordinarily used.

Tree planting. Tree planting in hard ground may be facilitated by the use of dynamite in breaking up the ground and preparing the hole. An advantage of making the hole with dynamite in preference to digging is the loosening of the hard material for some distance around the hole. This gives the roots of the tree a greater opportunity to spread.

Obstructions in drainage channels. Silt bars, ice, and jams in drainage channels are frequently removed with explosive when it would not be possible to accomplish the same result in any other manner. Charges of 60 per cent dynamite, 18 inches apart, in wet ground, can be fired from one primer, the concussion through the ground being sufficient to explode all of the charges.

SUMMARY

Definite instructions for the grade, quantity, and exact location of a charge cannot be given for specific blasting work. A certain amount of experimental work must be done if the most economical results are to be obtained. When bowlders are to be removed, the hardness of the rock will determine the quantity and the method. When stumps are to be dynamited, the root formation, the length of time the stump has been dead, and the condition of the soil will be the determining factors. For special work, such as breaking up hardpan, tree planting, and ditching, the manufacturer's instructions should be followed, only such changes being made as local conditions dictate.

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CHAPTER XI

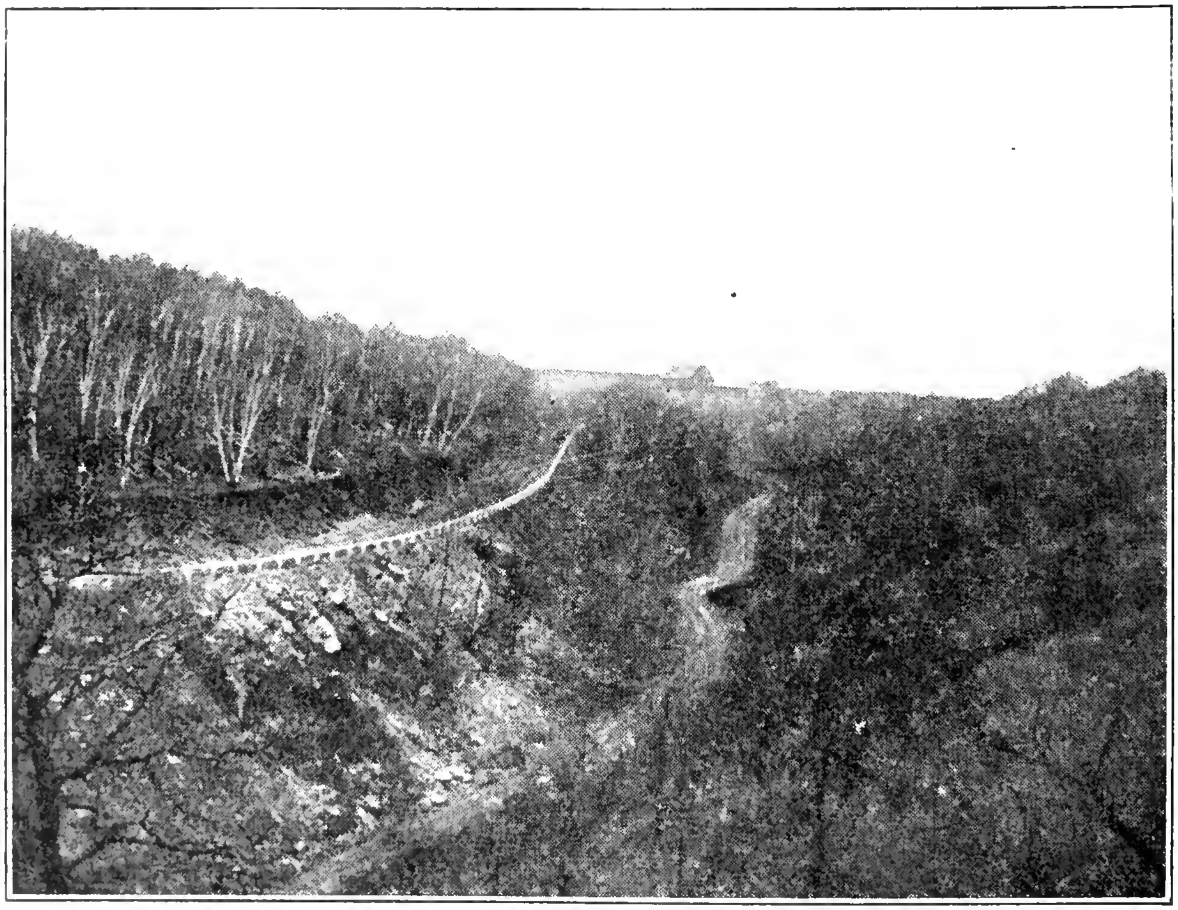
ROADS

Webster defines a road as "a strip of ground between two points of land, set aside for the passage of vehicles or persons traveling on foot." Roads have always had an important bearing on the destiny of nations, and history frequently refers to conditions made possible or impossible by them. The Roman conquests were first only to Roman road construction, for their roads followed the army. It was largely due to the good roads leading from central points, over which the Roman soldiers could rapidly move from one section to another, that Rome held the world in subjugation for centuries. Similar conditions existed in Peru and Mexico. Splendid roads for foot use, probably built for military purposes, were constructed from the seats of power in every direction. These serve to emphasize the fact that transportation is essential and that facilities for easy and rapid movement from one section of the country to another should be provided, if development and growth are to be stimulated. Roosevelt, in an address before a National Highway Commission, said, "A road is an indication of the civilization and intelligence of any people."

Development. The road problem is not new; neither is it one that is of interest only to civilized man, for we find that the savage tribes as well as animals of the lower orders are prone to move from place to place by the route which offers the least resistance. After having established a route, they continue to use it. The roads across many of the mountain passes or into the deep canyons were first made by mountain sheep or deer. The Indian, on his hunting trips, learned these trails and made use of them in his travels; the trapper packed his furs over them; the frontier settler widened them out for his wagon; and not infrequently the locating engineer followed them with a railway line—each in turn making and improving a highway that had originally served some animal as an easy route to pass from one feeding ground to another.

The road, in its earliest stages, may be considered as a signboard to show the easiest route of travel between points. In prairie country it indicates one which follows the highlands around swamps and leads to stream crossings. In mountain country it avoids precipitous slopes and leads to the more accessible passes.

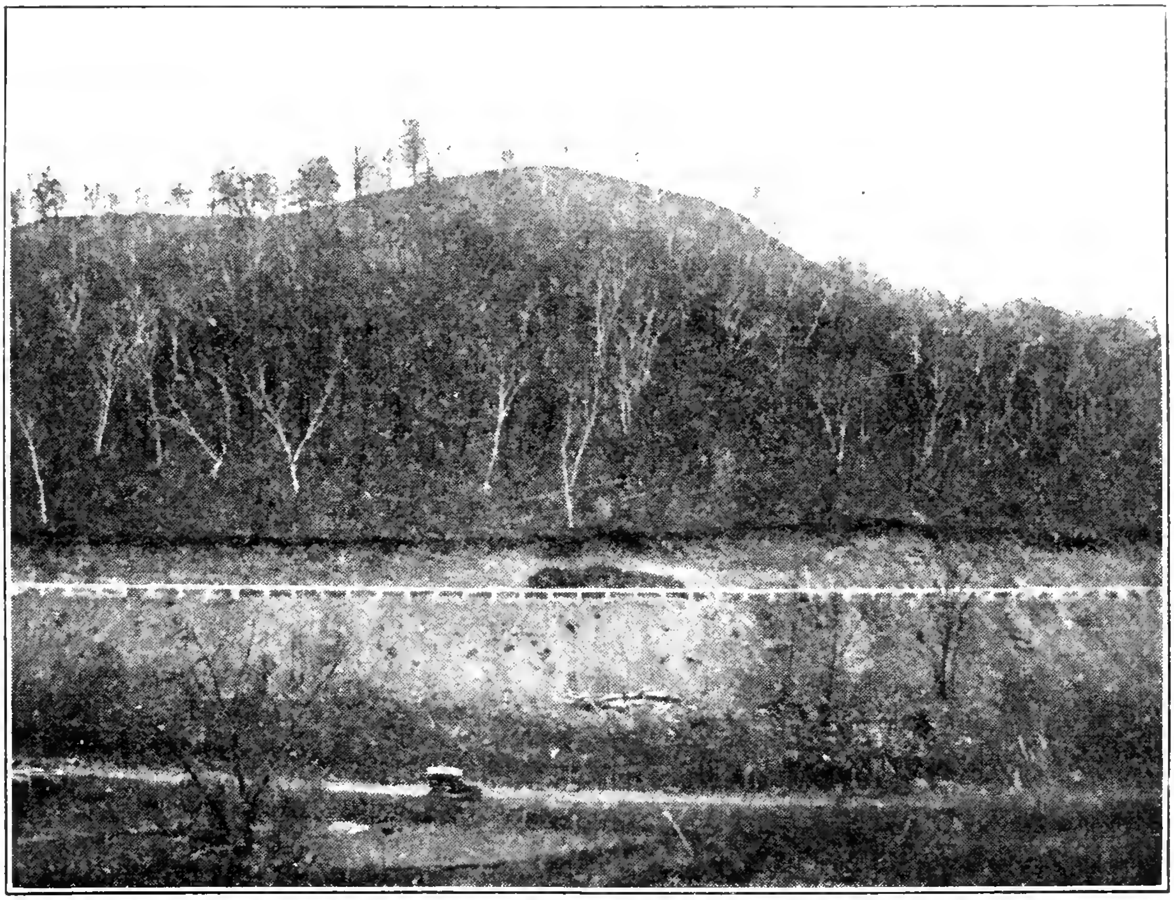
The load hauled is regulated by the road; the weight of the wagon and the number of horses attached are fitted to it. Hence, in a newly settled country, poor roads are to be expected and can seldom be avoided. As the country improves, the road requirements change and the road is built to suit the traffic. The problem becomes one of



After Minnesota Highway Commission

FIG. 174. *Showing location of old road and relocated new road*

constructing a road which will permit the hauling of a maximum load, at a maximum speed, with a minimum motive power. The game trail through the brush answers for the *travoi* of the Indian; the prairie sod broken by a log dragged from the front wheels of a wagon or a line of blazes through the timber answers the pioneer's purposes, but even the best oil-surfaced macadam road is scarcely satisfactory for the modern automobile and the heavy loads of our well-settled and highly intensified farming communities. Roads which a few years ago were considered everlasting and good enough for any community are now out of date and inadequate on account of the increasing automobile traffic.



After Minnesota Highway Commission

FIG. 175. *A section of the old and new road shown in Fig. 174*

Value of good roads. The benefits from good roads are both economic and social.

Economic advantages. Many of the rural districts have become so accustomed to poor roads that they do not realize their real cost unless it is directly called to their attention. A farmer sold 1,600 bushels of corn at 50 cents a bushel, to be delivered in February. His object in selling was to get the corn to the market before the roads broke up and the spring work began. On the day he was to begin shelling, it rained, the roads becoming impassable. When the roads again became solid so he could haul, it was in the middle of the oat-sowing season. He had to stop sowing oats, haul his corn to town, and sell it at 50 cents when the market price was 55 cents. He not only was on the road when he should have been in the field, but he lost $80. He attributed his misfortune to the weather: if it had not rained the road would have been good. It did not occur to him to look at it in the reverse order: if he had had a good road, the rain would not have delayed him more than a day. He could have held his corn until the price suited him without regard to the road. When the matter was presented to him in this light, he felt that he was paying a heavy tax for a poor road.

Social advantages. The social advantages of good roads are equal to the economic advantages. Good roads permit the country children to attend the town grade and high schools. They enable the farmer and his family to enjoy the concerts, lectures, entertainments, and religious exercises of the town and stimulate the organization of farmers' clubs, institutes, and other public meetings by making it possible for the people of the community to attend by spending only a short time on the road.

Uniformity of travel. One advantage of a good road is that it can be traveled uniformly during the year. Comparison of the traffic over poor and good roads was made in Illinois. Observations made simultaneously near seventy-two towns upon certain days of each month showed that roads are best in the summer and fall and poorest during the winter and spring. These observations showed that traffic is nearly uniform throughout the whole year on hard roads, while on muddy roads there is a decrease in traffic of over one-half or three-quarters during the spring months. For example, on a muddy road leading into Springfield in March there was an average of 65½ vehicles passing per day. On the same road in June the average was 389. In March on a macadam road near Peoria there were 166 vehicles, and in June 145. On an earth road near Carbondale there were 28 in March and 187 in June. On a gravel road near Decatur in March there were 240 and in June 270. This shows conclusively that traffic over poor roads in the winter and spring is less than on good roads.

FIG. 176. *A paved country road that will carry heavy traffic every day of the year. This road was formerly impassable in bad weather.*

Statistics indicate that there is no connection between the size of towns and the volume of traffic. The density of the population in the country is what determines traffic. Roads near small towns are as important as roads near the larger centers. Some country roads have more traffic than those near the large cities. The amount of money spent on a road should be in proportion to the traffic which it will carry. In many cases the traffic on the roads a mile or two out of town will warrant the expenditure of four or five times as much as on the more remote roads. It has been shown that earth roads are traveled very little during the rainy periods and that the necessary travel is at a great disadvantage. This causes the effect of poor roads to be shown in the moving of each year's crop. Every year there is a great rush to get the crops off before bad roads set in, since the products of the farm seem to be sold more in regard to the condition of the road than in respect to the requirements of the market. This comes all at once, and the tendency is to upset business, demoralize trade, and advance interest rates, and, as only a part of the crop is needed at one time, the railroads find it hard to handle the grain during the rush period. They could handle it more cheaply if it were shipped more uniformly throughout the year, and the grain could be stored more cheaply in the granaries on the farm than in the city elevators.

Good roads make it possible to move the farm products from the farm to the point of consumption as needed. The cost of hauling farm products in the United States is about double what it is in Europe, the comparison being made on the basis of the road conditions.

Draft and resistance. *Draft* or *tractive force* is the force exerted by a team or motor in drawing a load. The axle friction, rolling, and grade resistance which this force is obliged to overcome are known as *tractive resistance.* The resistance is high upon rough roads of considerable grade and at a minimum on smooth, level roads. The cost of transportation increases with the increase in the resistance offered. The Bureau of Public Roads, United States Department of Agriculture, has found that the tractive force required to move a ton on loose sand is 320 pounds, on the best gravel as laid for a park road, 51 pounds, on the best clay roads, 98 pounds, and on the best macadam, 38 pounds.

Distribution of load. The Michigan Agricultural Experiment Station made the following experiment to determine the influence of the position of the load on the wagon upon the draft. A comparison was made between the draft of the wagon when the load was equally distributed upon all four wheels and the draft of the same wagon when the load was piled over the rear axle. Two trials were made in each case. The draft of the wagon when the load was equally distributed was 149 pounds, and when almost entirely upon the hind wheels, 147 pounds; this is, for practical purposes, the same. These trials were made on a hard gravel road. Two trials in each case upon a blue grass sod showed that with the load distributed the draft was 167 pounds, and with the load on the front wheels, 289 pounds. These results show that where the road is firm and smooth it is immaterial whether the load is evenly distributed or not, but where the ground is soft the draft is increased if the weight is placed on the front or the rear wheels.

Point of attachment. A few experiments have been made to determine the influence of the point of attachment of the team upon draft. These tests were made upon a gravel road, in the first case level, in the second case with a grade of 6 feet to the hundred. In the first case, with the whiffletrees in a normal position, the draft was 188 pounds. When the power was placed at the end of the tongue, 9½ feet ahead of the ordinary point of attachment, the draft was 174 pounds. When the load was drawn up the grade mentioned, with the whiffletrees in the ordinary position, the average draft of two trials was 366 pounds. When the horses were hitched to the end of the tongue, as before, the draft was 379 pounds. These trials do not show a marked difference in draft which can be attributed to the point or method of attachment.

Width of tires. The width of tires has from time to time been a topic for considerable discussion. It is generally conceded that a wide tire is less detrimental to a road than a narrow one, the wide tire, to a certain extent, performing the work of a roller, tending to compact and leave the road surface in better condition than before the vehicle passed over it. A narrow tire has a tendency to cut the road covering and cause the surface to be more susceptible to water. The effect of the width of the tire on the tractive force depends entirely upon the condition of the road or the land surface over which the vehicle is passing. The wide tire is better so long as it does not cut into the surface, but when the load is sufficiently heavy to force the tire into the ground the narrow tire runs more easily. Experiments along this line indicate the following: On good hard roads and pavements there is no argument in favor of the wide tires; rather in favor of the narrow ones. On soft mud and slush where the tire will cut, a narrow tire is better; on soft ground or on sod the broad tire is the better, as it will carry a greater load without cutting. As a general statement it may be said that the broad tires keep the road in better condition and do not increase tractive resistance to a serious extent.

WIDTH OF TIRE AS RECOMMENDED FOR WAGONS OF DIFFERENT CARRYING CAPACITY BY THE BUREAU OF PUBLIC ROADS, UNITED STATES DEPARTMENT OF AGRICULTURE

Type of Wagon	Gross Weight Loaded in Pounds	Width of Tire in Inches
One-horse wagon	2,000	2
Light two-horse wagon	3,500	2½
Medium two-horse wagon	4,500	3
Standard two-horse wagon	6,800	4
Heavy two-horse wagon	7,500	5

Diameter of wheel. Experiments made to determine a satisfactory diameter of a wheel indicate that high wheels are best under nearly all conditions, but they are likely to become cumbersome, a fact which limits the diameter that may be used. The best height of wheel, considering convenience and tractive force, is one with a diameter of 30 to 36 inches for the front wheels and 40 to 44 inches for rear wheels placed on axles of equal length. Small wheels increase the draft on bad roads, rut the road more deeply, and cause greater tongue vibration than high wheels. On the other hand, they are much more convenient for loading, as the body of the vehicle stands lower.

Qualities of a good road. The qualities to be sought in a road are a flat grade with a smooth, dustless surface of a degree of hardness to withstand the traffic, and still sufficient elasticity to prevent injury to animals and jar to vehicles moving at ordinary speed.

Local problems. The conditions necessary for obtaining these requirements will vary with the climate, locality, and funds available. In the arid regions the road becomes dusty from continuous travel; in sandy regions, soft from the nature of the soil. In the alluvial areas of the humid regions they become soft from excessive moisture, and rough from being traveled while wet. As the road materials vary in each of these regions, the road problem becomes one of studying local conditions, material available, and funds at hand, and with these constructing a road which will approach as nearly as possible the ideal road.

Materials. To secure a good road, it is necessary to have a solid foundation which will not become soft by moisture or be destroyed by erosion, and then an impervious covering that will shed the storm water and carry it to the side ditches. The material for this covering is the bone of contention among road builders and is the problem that confronts many of our agricultural communities. It is here that local conditions should be studied and the road builder use his ingenuity and experimental abilities to find at hand a material that will answer the purpose and be within the pocketbook of the district. Various materials are so used and approach to a greater or less degree the ideal road surfacing, according to the locality where they are used and the care exercised in construction and maintenance. Common earth roads may be very much improved if the puddling properties of the soil are developed and the soil kept in good shape with the road drag. Other materials used in road construction, some to a very limited extent and others widely, are as follows: a mixture of sand and clay, burnt clay where fuel is plentiful, shells along the coast, gravel and coarse sand as found in natural banks, broken stone of the more common geological rocks, wood in the form of planks for clay roads and as sawdust, bark or straw for sand roads, oil, asphalt, and tar as a binder on sand, gravel, and broken rock, bituminous concrete, asphalt, paving brick, and cement concrete. Such materials have proved satisfactory in many localities, but it should be understood that the method of treating a road with some of these in one locality may not be satisfactory in another, and that there is need for careful experimental work with road-surfacing materials in new localities.

Construction. There are certain underlying principles involved in the construction of roads regardless of the nature of the covering. In agricultural communities the location of the road is usually determined by the land lines, there being a strong sentiment against securing better grades by locating the roads around hills rather than over them. The location of the road on a section line frequently involves a heavy cut and fill and also the use of steeper grades than might be necessary if more latitude were allowed in the location. In localities where more choice of location is permitted, better roads can be secured for less money by the expenditure of some time and the exercise of judgment in making the location, as is done in the case of railroads. The question frequently arises between the relative desirability of having a rise and fall or increasing the length of the road. It has been demonstrated that it takes approximately the same power to raise a load through one foot vertically as to haul it 20 to 30 feet horizontally along an ordinary dirt or gravel road. Therefore, to eliminate a foot of rise, the length of the road may be increased 20 to 30 feet. It must be remembered, however, that the increased length of line adds to the cost of construction and maintenance, while cutting the grade would practically add only to the cost of construction. If the grade is short, it is cheaper to cut it down than to go around.

In any case the maximum grade is that which determines the load that may be hauled over any section of a road, and it should always be the object to reduce the grade to a minimum. It will not pay to go to a great expense in smoothing the surface if the grades are not cut down correspondingly. In comparatively level areas of prairie country the grade can be limited to 5 feet in 100. Whenever practicable this should be considered as the limit of grade for roads. In hilly sections or where road construction is in its infancy, grades as high as 10 feet in 100 are used. It should be remembered that one hill may limit the size of the load that can be hauled over the entire road.

Drainage. Water is the natural enemy of roads, and seldom will a place be found in which the road builder will not have to combat this destructive element in some form. Even in the arid regions the erosion caused by the sudden downpours of rain that occasionally occur renders long reaches of road impassable. Drainage is the foundation of road improvement, and until the disposal of water has been provided for, there is little permanent road improvement. In the prairie states thorough drainage may safely be said to solve one-half of the road problems. Work properly spent in draining is for an improvement that will be required regardless of the nature of future traffic or materials used in the superstructure. In swamp or wet areas drainage should be encouraged before road building, for the reason that drainage means an increased income from the land, which makes the road tax less of a burden to the landowner. Drainage, of itself, improves the roads, and permanent bridges and culverts cannot be economically constructed until the drainage systems are completed. Many of the rural road men are not aware of the fact that the building of a high road grade across wet land is only a makeshift for drainage, that a good tile or open ditch would remove the need of the grade, and that water standing along a road grade saturates the foundation of the road to the level of the standing water and then is raised by capillarity to the surface of the road and in the end destroys the road regardless of its surface covering.

Cross section. Grading is always needed to a certain extent to give the roadbed the proper shape and to make the most economical use of the covering. The cross section of the road will be determined by the local conditions, such as the volume of traffic and the materials for construction. The forms of the cross section have changed somewhat, owing to the increased number of motor cars used. Since a high crown has a tendency to cause side-slipping when it is wet, crowns that were formerly regarded as satisfactory are now made much flatter to accommodate high-speed automobiles. At one time drainage was the controlling element in the degree of rise that was given to the center of the road above its edges. This is illustrated by Figure 177. In the Roman road there was a permanent base with a rock covering, and, as it could not be injured to any great extent by moisture

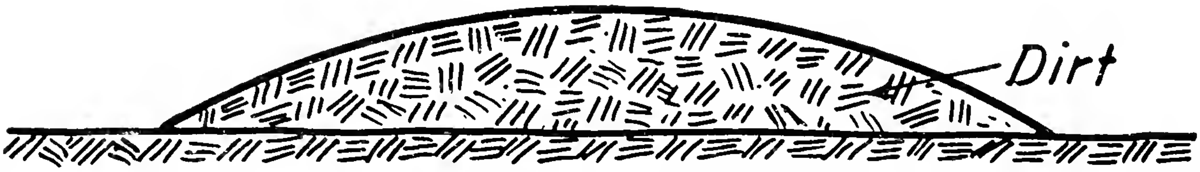


FIG. 177. *Cross section of the English earth road of an early date. Note the great convexity to keep it dry.*

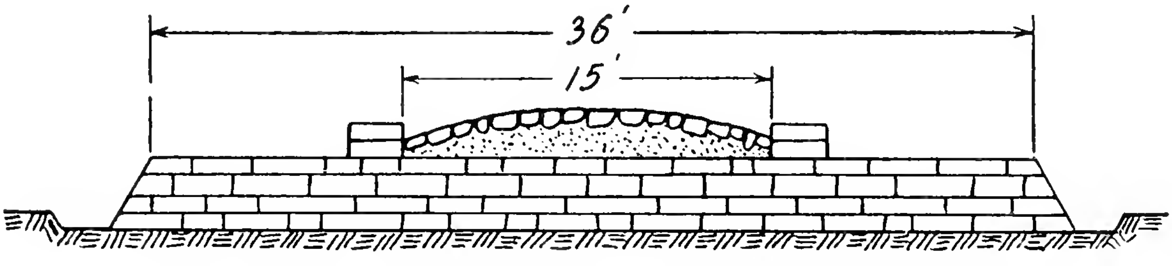


FIG. 178. *Cross section of a Roman military road*

it had a comparatively flat crown. The English roads built somewhat later were entirely of earth, and in order to be at all passable in wet weather they were given great convexity.

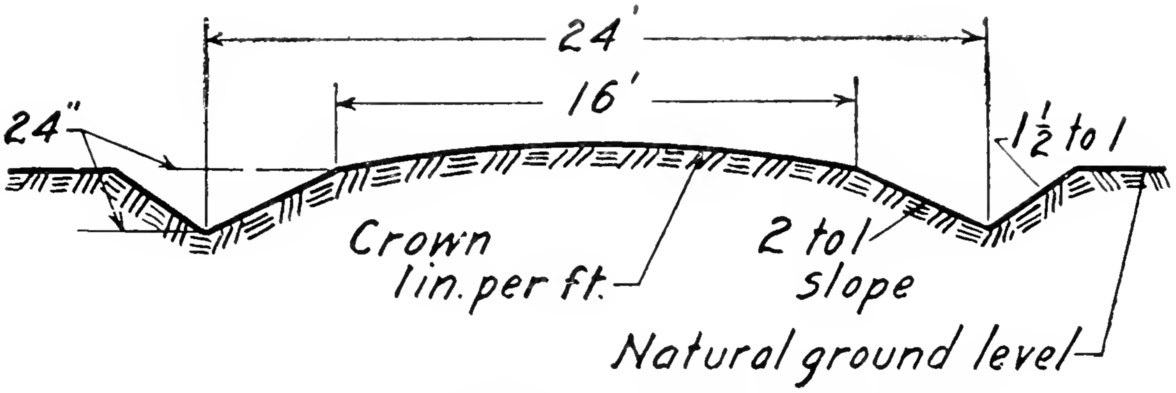


FIG. 179. *Cross section of a properly shaped loam road*

Kinds of roads. Roads are known under different names according to the material used in their construction.

Loam. A loam road (Fig. 179) is graded to the proper shape and has a cross section of such material as is available.

Clay. A clay road is graded and the surface covered with a coating of clay either hauled from a distance or taken out of the side ditches.

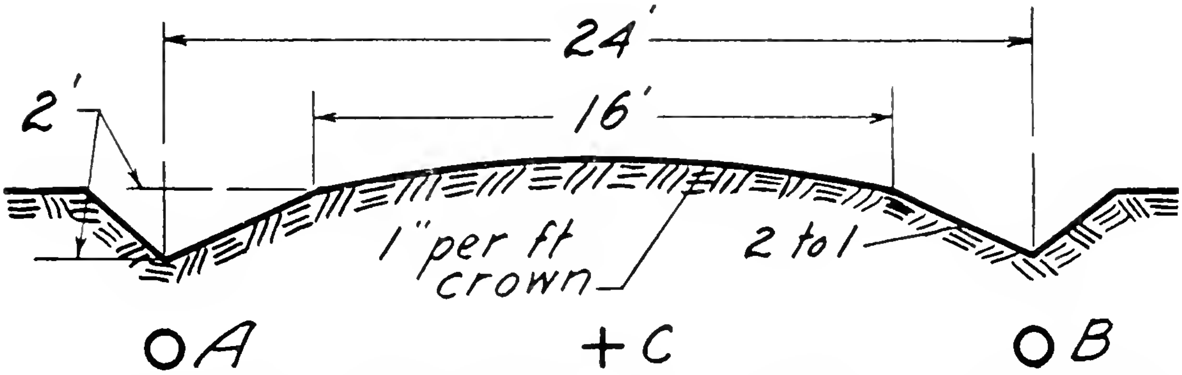


FIG. 180. *Cross section showing methods of drainage. A roadbed should be properly drained regardless of the nature of the surfacing. On land that is thoroughly drained a tile at A or B may be sufficient. On a new road it is desirable to place a tile drain at C, but on an old road this may become very expensive because of the difficulty in digging. In wet, heavy soils or for wide roadways tile should be placed at both A and B. If the tile is placed only on one side of the road, it should be on the side from which the water is coming, in order to avoid seepage. If water is permitted to pass under the roadbed, it will be raised by capillary action and soften the surface, causing the road to settle.*

Gravel. A gravel road is graded and then covered with a coating of gravel. The gravel layer will vary from 4 to 10 inches in depth. It should contain sufficient clay or binding material to cause it to pack and become hard. For country roads the packing is usually done by the traffic. More satisfactory results are obtained when the gravel is spread in several layers, sufficient intervals being allowed between the placing of the layers to enable the last one placed to become packed and solid before another is put on. A first-class gravel road is made by a careful selection of the materials, spreading in layers, sprinkling, and rolling, the road being finished and ready for use in a comparatively short time. Where the original roadbed is composed of fine sand, a layer of clay should be spread over the sand before the first coat of gravel is spread.

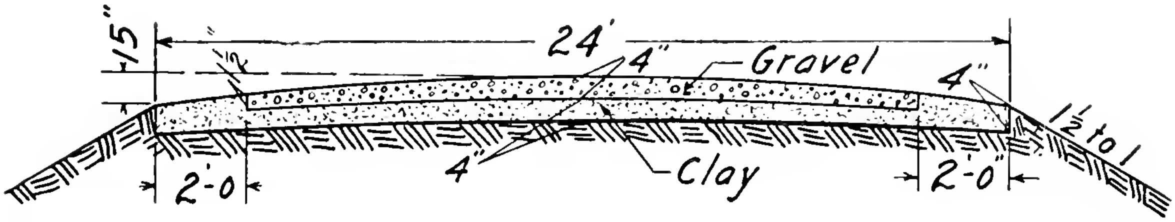


FIG. 181. *Cross section of a gravel-clay road, built on very sandy soil. This road gave excellent satisfaction.*

Macadam. A macadam road (Fig. 182) is one in which the covering is made of broken stone. Coarse large stones are placed as a base and thoroughly rolled down. A layer of small stone or good gravel is then placed on the base and rolled. The depth of the covering and the size of the materials used vary greatly according to the location and traffic expected and the nature of the materials.

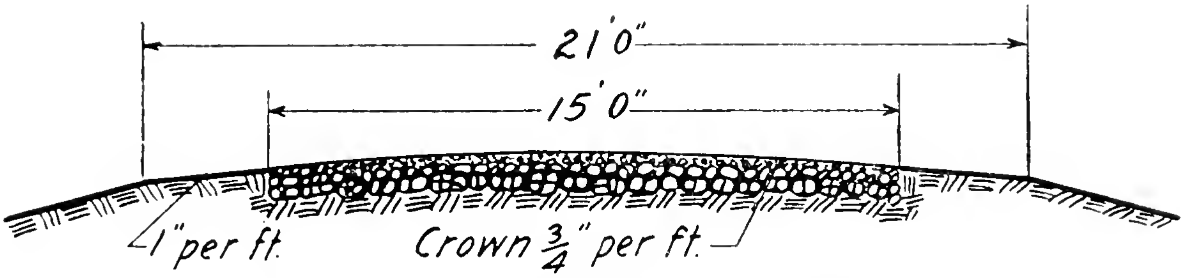


FIG. 182. *Cross section of a macadam road*

Telford. A telford road (Fig. 183) is one made by the method of laying a pavement of rough stone over a prepared grade and placing on top of this pavement a layer of broken stone or good gravel, which is thoroughly rolled. This class of road is not used much in the western country at the present time.

Oiled. The use of rapidly moving motor cars driven by the rear wheels has been found to have a very wearing effect on earth, gravel, and stone roads. The wheels grind the material into a powder, which rises as dust and is blown from the road. As a result the thickness of the road covering is rapidly decreased. To overcome this it is necessary to place over the surface of the finished road a strong binder of some nature that will hold the particles together and prevent the formation of a powder which the wind can remove. This is best accomplished by means of a coating of heavy oil, which will penetrate the surface and unite the particles into a solid mass, spread over the road after construction or at frequent intervals. Any of the roads above described can be treated with oil and are then known as oiled roads. The success of oiling will depend upon the character of the oil used and the nature of the road covering. Either too large or too small a quantity of oil will not give good results. A thin oil does not furnish a binder of sufficient strength, and a thick oil will not penetrate deep enough to bind firmly. Thick oils are frequently poured when hot in order that their penetrating qualities may be increased. Oiling has not been found very beneficial on clay and loam roads. It gives the best results on good gravel or broken stone.

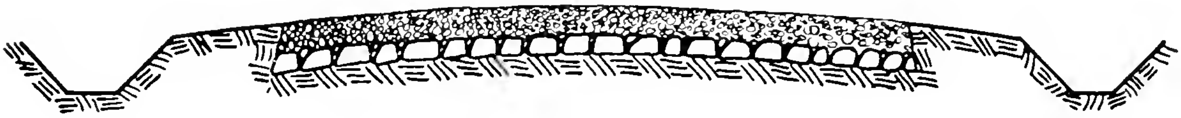


FIG. 183. *Cross section of a telford road*

Pavements. Country highways as above described have been found fairly satisfactory for horse and light automobile traffic. To secure permanency and low maintenance cost on through roads subjected to the heavy loads and high speed of motor vehicles requires some type of construction similar to city pavements. Pavement construction for country highways has been developed in the country since the advent of the motor car and is of two general types: (1) some form of a block laid on a solid foundation; (2) a tough, hard material that will stand the wear united in a homogeneous mass by a cementing material.

The type of construction most favored for this purpose is a good foundation covered with a wearing surface made of a mixture of tough, hard sand and pebbles or broken stone bound together by a cementing material. The cementing materials are of two kinds: (1) bitumen, a material found in natural asphalt, asphalt, petroleum oils, and tar, in which the cementing qualities are physical, being due to sticky properties which develop when the material is heated; (2) Portland cement, in which the cementing properties are due to chemical action set up when water is added.

Block paving. Block paving materials that have proved satisfactory for pavements under certain conditions are vitrified brick, stone block, wood block treated with a preservative, and bituminous block. The blocks are usually laid on a foundation made of Portland cement concrete 4 to 6 inches thick. The block pavements for country highways are used only to a limited extent.

Bituminous surfaces. Bituminous road surfaces are constructed in a variety of ways and under numerous trade names. Bitumen is the substance that gives certain oils previously mentioned their value as road material. A thin oil applied to a road surface is known as a dust layer. A coat applied to the surface and then covered with rock screening or sand is called a bituminous carpet. A bituminous macadam is a macadam road properly built and shaped and then treated with a hot bituminous binder which penetrates to a depth of approximately one inch in sufficient quantities to bind the surface in a solid sheet. A bituminous concrete road has a wearing surface 2 inches thick of a properly proportioned mixture of stone dust, sand, pebbles or broken stone, and bituminous cement, all of which are heated, mixed, and spread while hot on a foundation of Portland cement concrete, macadam, or gravel. Sheet asphalt pavement has been used for many years in the cities and is made of natural asphalt mixed with sand and spread on a Portland cement foundation 4 to 6 inches thick. The asphalt is put down in two layers, an elastic layer 1 to 1½ inches thick and a wearing surface 2 inches thick. Both coats are mixed, spread, and rolled while hot.

Portland cement concrete. A base for various forms of pavement has been constructed of burned rock cement for many years. The fabrication of a wearing surface using Portland cement as a binder is a comparatively recent development which is coming rapidly into use in all parts of the country. It is placed on the road in either one or two courses. The single course is 6 to 8 inches in thickness, the center being slightly thicker than the edges. The sand and pebbles or broken stone are selected for their wearing qualities and proportioned according to their grading as to fineness. The materials are mixed on the site, placed, finished to the proper surface, thoroughly tamped or rolled, and properly cured.

Local roads. In certain localities various materials different from those specified are used for road construction. Such materials usually have only local application, but may be very effective and satisfactory where used, while they would not be practical in localities differently situated.

Corduroy. Corduroy roads are used in timbered countries and consist of brush, poles, or logs placed across the line of the road. In roads crossing swamps the timber material is packed closely together. Occasionally it is used without any covering, but it will last longer and be much smoother if the timber is entirely covered from one end to the other with a coating of sand, clay, or gravel.

Plank. Plank roads (Fig. 184) have frequently been used where a temporary road is needed and sawed timber is the cheapest road material available. Planks make an excellent road, but their life is very short.

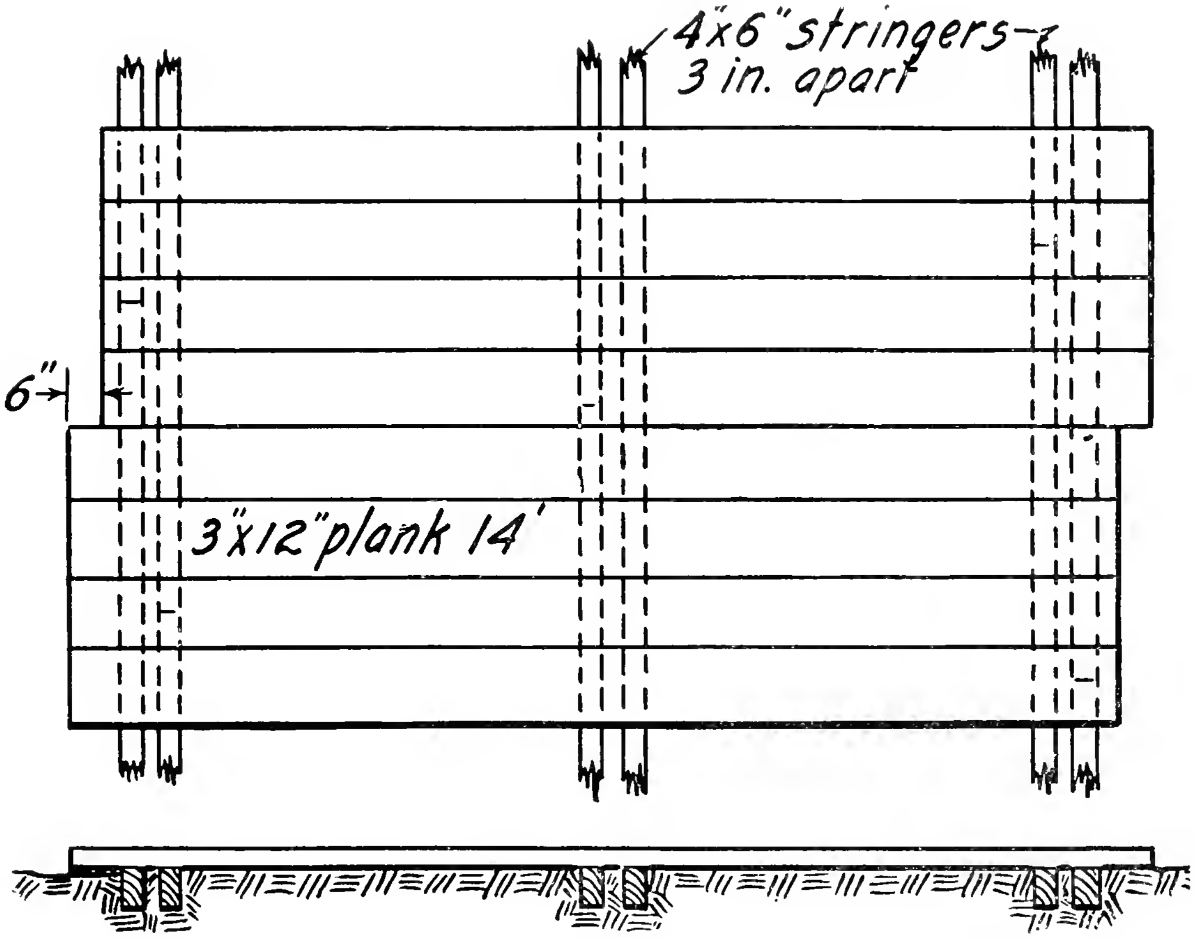


FIG. 184. *Cross section of a plank road. Note the 6-inch offset of eve fourth plank to assist in getting a wheel back on the road.*

Sand-clay. Sand-clay roads are used in localities where neither rock nor good gravel is found. They are made of clay and sand mixed in such proportions that the mixture will become neither dusty in dry weather nor sticky in wet weather, the clay being in sufficient quantity to bind the sand thoroughly into one mass.

Burned clay. Where fuel is available and natural road-making materials are scarce, fairly satisfactory results have been secured in road construction by the method of covering the roadbed with dry timber and throwing clay from the side ditches over it. The timber is then fired, and the result is a softly burned clay which makes a good road in wet weather but has a tendency to become dusty in dry weather. Only a few localities have the necessary fuel available and the proper kind of clay for making such a road. The burning must be superintended by an experienced person who understands the arranging of the fuel and clay to get the best results.

Sand. In fine, sandy soil where clay and gravel are not available fairly good results are secured by a mixture of some vegetable matter with the sand, such as sawdust, tanbark, straw, or worthless hay. The vegetable matter should be placed on the road in thin layers, and as soon as it has been worked in by the traffic another layer placed.

Shell. Shells make a satisfactory road covering in localities along the coast where they can be secured.

Charcoal. Charcoal has been used for roads to a limited extent by the burning of refuse wood on the road, similar to the method of making burnt-clay roads.

Progressive road building. In the greater number of localities it is not practical from a financial standpoint to secure the ideal road at once. Where this is true, attention should be given to future needs, such that the work will not be entirely wasted for later improvement. Good locations should be selected and roadbeds graded and drained. These will be advantages for any type of superstructure. If it is not possible to prepare a road entirely, it should be done in such a way as not to increase the cost of later developments. A sufficient width of roadway can be left, and the greater part of the earth for grading taken from one side, the other side to be completed at some time in the future. Too often grades are thrown up or ditches made that must be destroyed by later work, making the cost greater than if they had never been made. While it is true that the exigency of the case or the shortage of money may compel the construction of road work that may have no value in future improvement, it is very seldom that such work will add to the cost if the future is considered at the time of construction.

Maintenance. One of the most important elements of road education is to recognize the need of systematic and thorough maintenance, for roads, like nearly all other works of men, require constant repair or they rapidly disintegrate. The success of many of the cheaper road-surfacing materials depends almost entirely on the care with which they are maintained. If a community can be educated to prepare a roadbed properly by draining and grading and then to adopt a proper system of maintenance, the road problem is practically solved, and the road will be surfaced by the best materials obtainable as rapidly as a demand arises for better roads than natural conditions afford.

Repairs. In repairing old roads, the grader should be started in the spring and kept in continuous operation until the end of the season. Units of work should be laid out in advance such that they can be taken up successively. Otherwise time is lost in moving from one location to another. The same teams and operators should be kept on the grader throughout the season. Wherever water stands in the roadway or by the roadside, or wherever the ground remains soft or swampy in the spring and fall, better drainage is needed. Roads should be inspected after heavy rains and during the spring freshets. The work of a few minutes in freeing drains from obstructions or diverting the current of water into a proper channel will prevent erosion which would require the work of several days if neglected. Surface water should be disposed of in small quantities if possible. Large volumes along the road are destructive and hard to handle. Drains should be led into natural water courses as often as possible, and tile instead of open ditches should be used wherever it is practical to underdrain. Culverts should be given a free outlet such that water will not freeze in them.

Road drag. For earth and gravel roads the most satisfactory method of maintenance is by passing over them after each rain with a road drag (Figs. 185, 186). These road drags were formerly made of a split log, from which came the name "split-log drag." They can be made of sawed lumber, but at the present time all road machinery companies manufacture and place on the market metal road drags superior to the wooden ones. Successful results from road dragging are obtained only by thorough and systematic work. Whenever there has been enough rain to wet the surface of the road and cause it to work up under the traffic, the drag should be used. The length of time which

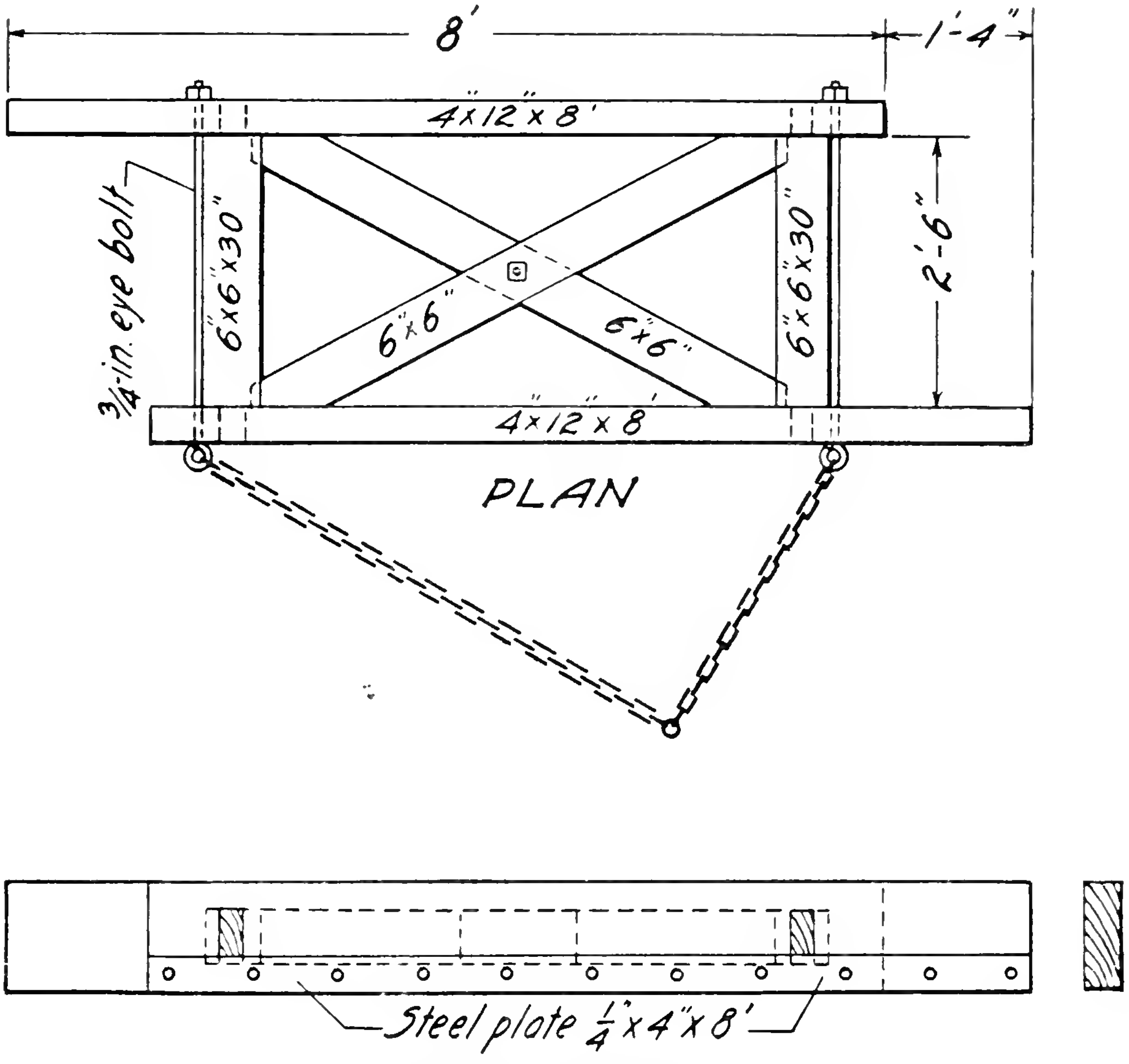


FIG. 185. *Construction details of the King road drag*

should elapse between the end of the rain and the dragging will depend upon the material of road surfacing. Surfaces that contain sand can be worked much sooner than those largely clay. Some experimental work is required on each road for determining the time that will give the best results. The man employed to do the dragging should be so situated that he can get on the road at the proper time, and he should not have the care of a larger section than he can pass over within reasonable time limits.

FIG. 186. *Use of the King road drag*

The principle on which road dragging benefits the road is that of puddling the soil. Any soil containing clay becomes tough and impervious to water with working and tamping while wet. Low places in barnyards hold water even though underdrained, owing to the tramping of stock which causes puddling. The use of the road drag on the wet road is the application of this same principle. The drag fills up all tracks and ruts, and the traffic then packs it. One of the objects of the drag is to obliterate all tracks and marks so that teams will not travel in the same place. When ruts are formed on the road they hold water, wheels running in these ruts carry out the soft material and permit the water to penetrate deeper, and in time the wheel goes through the puddled surface of the road covering and the road becomes impassable. If these ruts are not permitted to form, water falling on the road surface and the traffic tend to pack and consolidate it and place it in a waterproof condition which will shed the next rain rather than hold it. In road dragging the drag should be operated so that all small ruts and holes are completely filled, and the surface kept smooth and sloping to the side ditches in such a way that the surface water can readily run to them. When a ridge is formed on either side of the roadway, or holes and depressions wear in the surface which the road drag will not correct, the road grader or other method should be used for repair and the crown placed in such shape that the road drag can again perform its work properly.

Maintenance costs. The following table gives the cost of maintaining country roads made through ordinary agricultural land in Dodge County, Minnesota, for the year 1916:

Township	No. of Miles of Road Maintained by Dragging during the Year	Price per Mile per Round Trip	Average Cost per Mile the Year
Ashland	50	$0.60	$13.26
Canisteo	40	.50	12.50
Ripley	58	.75	7.98
Vernon	50	1.00	7.30
Hayfield	53	.75	12.62
Wasioja	......	.75	....
Mantorville	50	.55	9.33
Claremont	45	.70	9.65
County	102½	.72	25.83

Planning work. In the preparation of plans the work of the successive years should be kept in view and laid out before the men are brought on the ground. Such number of men and teams should be kept on the work as can be properly directed and kept steadily at work. Arrangements should be made for having all necessary implements in good repair and on the road when needed. All work should be done with a view to permanency and durability. The work should not be done at a season when the road will be left in a worse condition than if no work had been done.

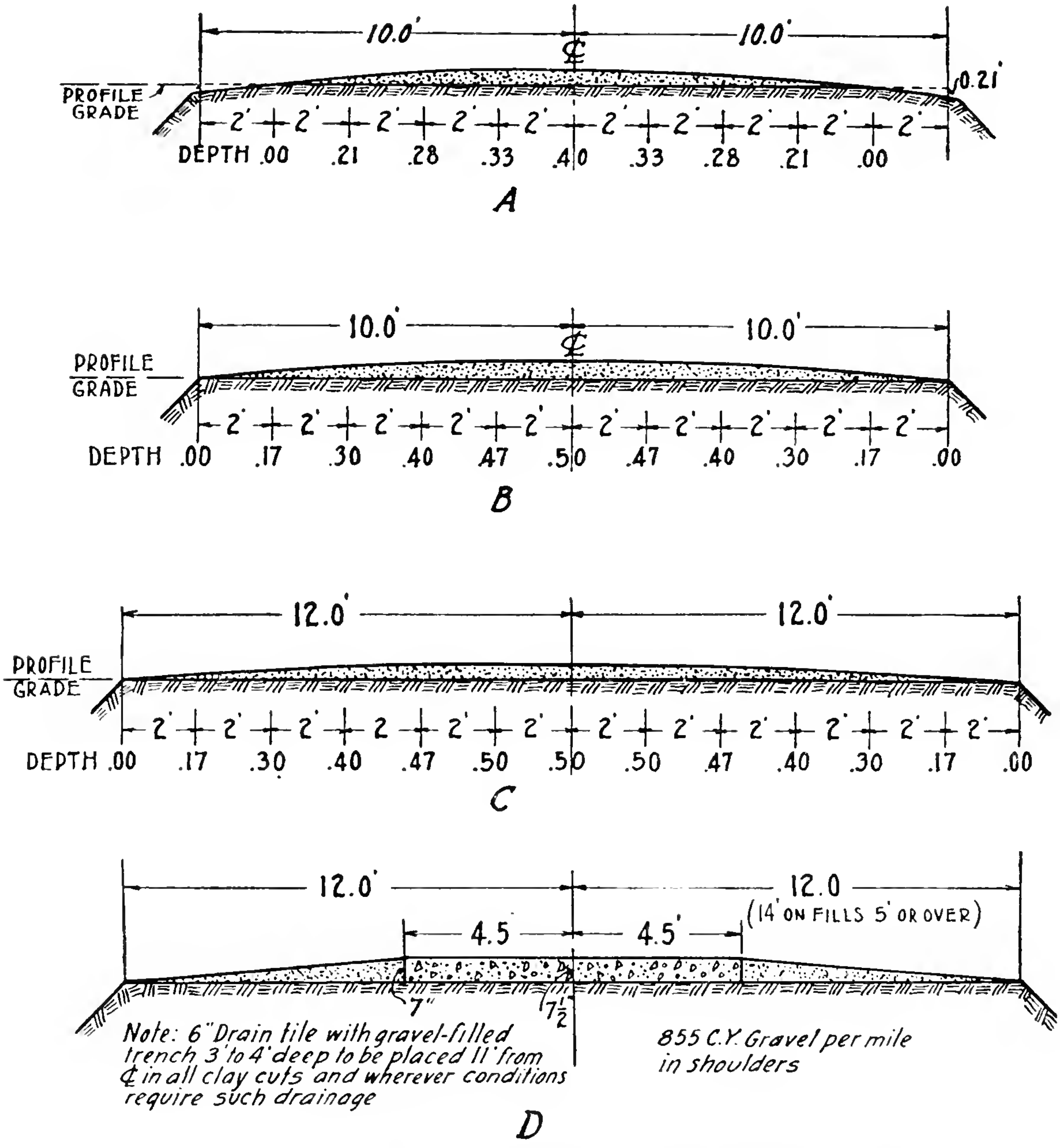


Fig. 187. *Standard surfacing sections of the Minnesota Highway Department for secondary trunk or primary state roads*

A—Gravel surfacing requiring 800 cubic yards of gravel per mile
B—Gravel surfacing requiring 1200 cubic yards of gravel per mile
C—Gravel surfacing requiring 1600 cubic yards of gravel per mile
D—Nine-foot concrete roadway with gravel shoulders

Road administration. The problem of proper and adequate road administration is one on which there is a number of different opinions. Some believe that road administration is a problem for the state or the nation, though the majority of landowners are opposed to centralization and do not want the national or even the state governments to interfere with the local road policy, except in the matter of giving a boost with an occasional appropriation to be spent on certain definite stretches of road. The problem of how to develop roads so that those deriving the most benefit will pay their just share without throwing the burden on the few has not been satisfactorily solved.

Labor-tax vs. cash-tax system. Some people favor having the state develop its roads by means of the labor-tax system alone, all able-bodied men being required to put in a certain time of each year on public road work. This system has been abolished in most of the northern states. On pioneer roads, where money is scarce, the labor system, or the payment of a road tax in labor by the individual owner of the property subject to the road tax, is desirable, but, as conditions improve, this method becomes unsatisfactory. The more progressive states are dispensing with the labor system and requiring that the road tax be paid in cash. It has been found in practice that the best roads are built and maintained where the labor system has been abolished and the work done by labor regularly employed and properly supervised.

The first step in road making in many rural communities is to replace the old labor-tax system by a cash-payment system — not that the labor system is wrong, but it has served its time and should be replaced by a better method. The labor system has done excellent service in the improvement of pioneer roads, and is the only method that can be used in a newly settled country; but, like the log house, it should give way at the proper time. When the time comes that the road should be built to accommodate the load, there is practically no further improvement by the labor system, for different methods must be used. The arguments against the labor system are summed up as follows: The roads are not worked at the proper season of the year, because the farmers cannot leave the fields at the season when road work should be done. There is no general plan and, as a result, much of the work is of no benefit to the road. Since the work is nearly all done at one season, it necessitates much moving of machinery from one part of the road to another, and the bringing together of strange horses for only two or three days at a time and using them on work to which they are not accustomed. Repairs are not made when necessary. This is an essential feature, for it often happens that if a break were repaired immediately it could be done in a few hours, but when let go two or three months the work requires several days. The cost of supervision is high in the labor system owing to the time spent in calling out the farmers, showing them where to work, looking after the machinery, and directing the work. Records show that supervision under this system is seldom less than 40 per cent of the total tax, while under the cash system it varies from 6 to 10 per cent. In Ramsey and Hennepin counties, Minnesota, the amount of tax for that purpose under the labor system was 40 per cent, but since the adoption of the cash system only 7 per cent. If the cash system is adopted and the money expended under proper supervision, a surprising amount of good road work can be accomplished in a few years.

SUMMARY

The world's food supply passes in wagons over the country roads; therefore it is of importance to have good roads. The history of roads indicates that they pass through a state of development, and this continuous development should be encouraged. The principles of road building should be taught as adapted to local conditions. Drainage should be promoted before permanent road construction. Roads should be passable at all times of the year. This adds regularity and stability to the trade of the country. Roads can be bettered with the material and money at hand. The farmer loses by not being able to market when prices are high. Good roads will assist in solving the social problems of the farm. Good roads can be had in nearly all localities by sandwiching some local material between good drainage and eternal vigilance in maintenance.

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Literature relating to the various phases of the public road problem and methods of construction and maintenance may be had upon application to the Bureau of Public Roads, United States Department of Agriculture, Washington, D. C. The subject upon which information is desired should be named. Similar information can be furnished, to a limited extent, by the state highway commission or the state engineer's office, usually located at the capital of the state.

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CHAPTER XII

FENCING

PRIMARY CONSIDERATIONS

It has been said that agriculture is as old as the world, and from what can be learned from early writings fences are as old as agriculture. The fence of ancient times was usually constructed of stone or sun-dried brick. The modern fence has gradually developed from walls, hedges, and other more or less crude forms, until it has reached its present-day degree of perfection. In this development a large amount of time and money has been spent in improving old and inventing new types.

Various considerations make it advisable and necessary to have a strong, lasting, and well-appearing fence between the fields of rotation and along the farm boundaries which will give satisfactory service and be economical in construction. To give good service it must turn stock without injuring them, and to be economical it must be built as cheaply as is consistent with durability and a proper performance of the desired service. A fence which has a low first cost is not necessarily economical, for its life may be such that it will be expensive in the end.

It is impossible to specify one fence that will fit all needs on all kinds of farms. The special type adapted to the use of any farmer depends upon the kind of stock kept, the permanency desired, and the materials, labor, and money available. A fence for hogs need not be so high as one for cattle, but a cattle fence does not need to be so tight near the ground. A fence on a horse-breeding farm, where no other stock are kept, does not need to be close at the bottom, but must be high and made of material which will not injure a horse. Personal judgment and preference vary also with regard to details of materials and methods of construction.

Circumstances frequently occur which make it necessary to construct a temporary fence, as in cases where the farm plan has not been decided upon and the field boundaries are only temporary. When the farm plans are complete and permanent lines are established between fields, it is advisable to have a strong and permanent fence which will turn horses, sheep, cattle, and hogs. Good fences around a field make it possible to utilize much pasture that would otherwise go to waste.

TYPES OF FENCES

Stone fences. Pioneer fences are made of such materials as happen to be at hand. Where stone is plentiful, stone fences are constructed. The construction of such a fence accomplishes two purposes, the removal of objectionable material from the fields and the building of a lasting and substantial fence. These fences are made about 2 feet wide at the bottom, 4½ feet high, and 18 inches across the top. The larger stones are placed on the bottom, slanting a little toward the middle. Long stones are occasionally laid from one side to the other to serve as a binder, and large flat stones are placed on top. The life of such a fence, properly constructed, is practically indefinite. If loosely laid up, it may be pushed over by stock or toppled over by alternate freezing and thawing.

Rail fences. In localities where wood is plentiful, poles are cut and laid up as a rail fence (Fig. 188), or the ends flattened and nailed to posts. All trees along the line that will serve are used as posts. Where straight-grained timber of sufficient size to split is available, fences are built of rails. The rails are approximately 12 feet long and from 4 to 6 inches thick. The fence is built from seven to eight rails in height, with the rails overlapping a foot at either end to serve as a lock. The height of the fence is increased by two stakes placed at each lock, set in the ground and crossing each other on top of the lock. A rail is laid across these stakes. Such a fence is known as a rail fence with *stake and rider.* The bottom rail is known as the *worm* and is kept reasonably level by means of a block of wood placed under each lock. Each panel of the fence is on an angle with the preceding and succeeding panel. The width of ground covered by the fence is approximately 6 feet, the

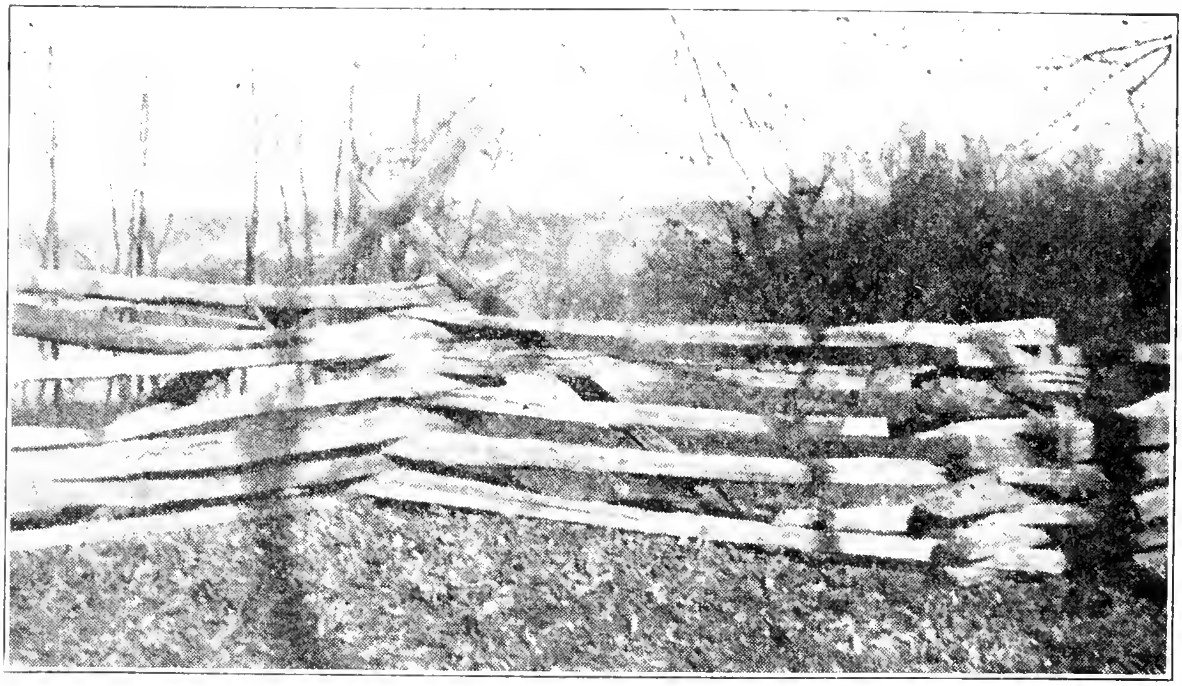


FIG. 188. *An old rail fence*

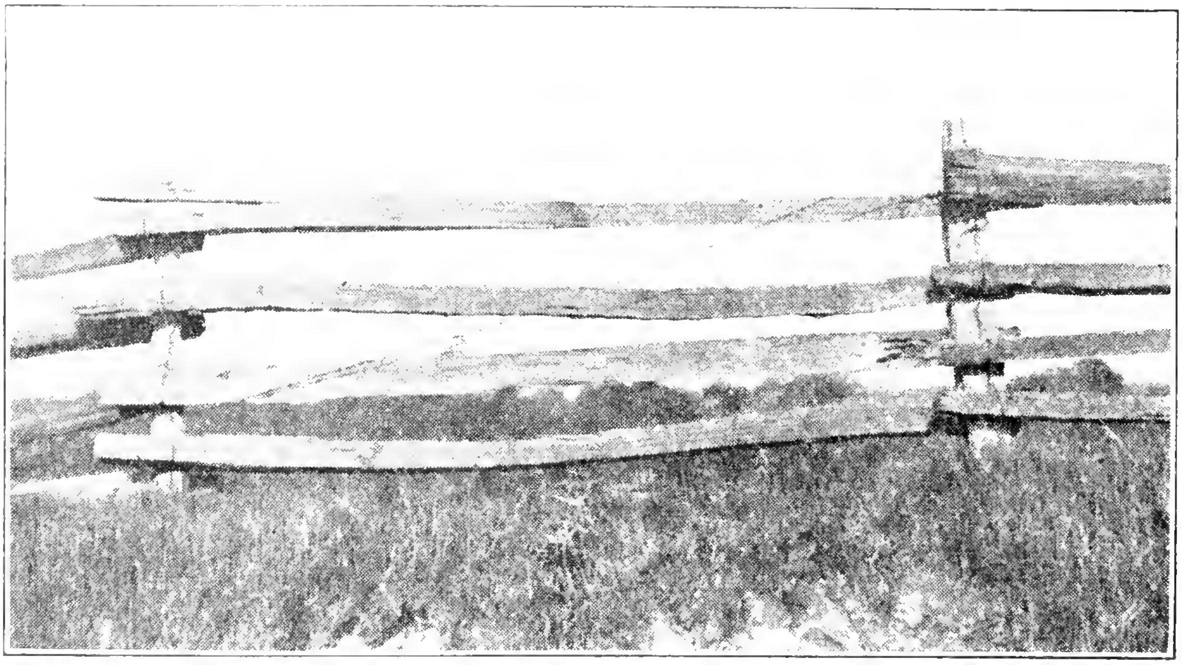


FIG. 189. *An old flat rail fence repaired with a barbed wire*

actual line on which the fence is laid being the center of this strip. Flat rail fences (Fig. 189) are made by means of flattening the ends of the rails and either nailing them to posts or driving the rails into mortises cut in the posts. Such a fence requires considerably more work in its construction than a rail or worm fence, but it is straight and wastes less land.

Stump fences. In the clearing of new land, stumps that have been removed by explosives or by a stump puller are frequently piled in such a manner as to make a very satisfactory temporary fence (Fig. 190). When they have decayed enough to prevent their use as a fence, they are easily destroyed by fire.

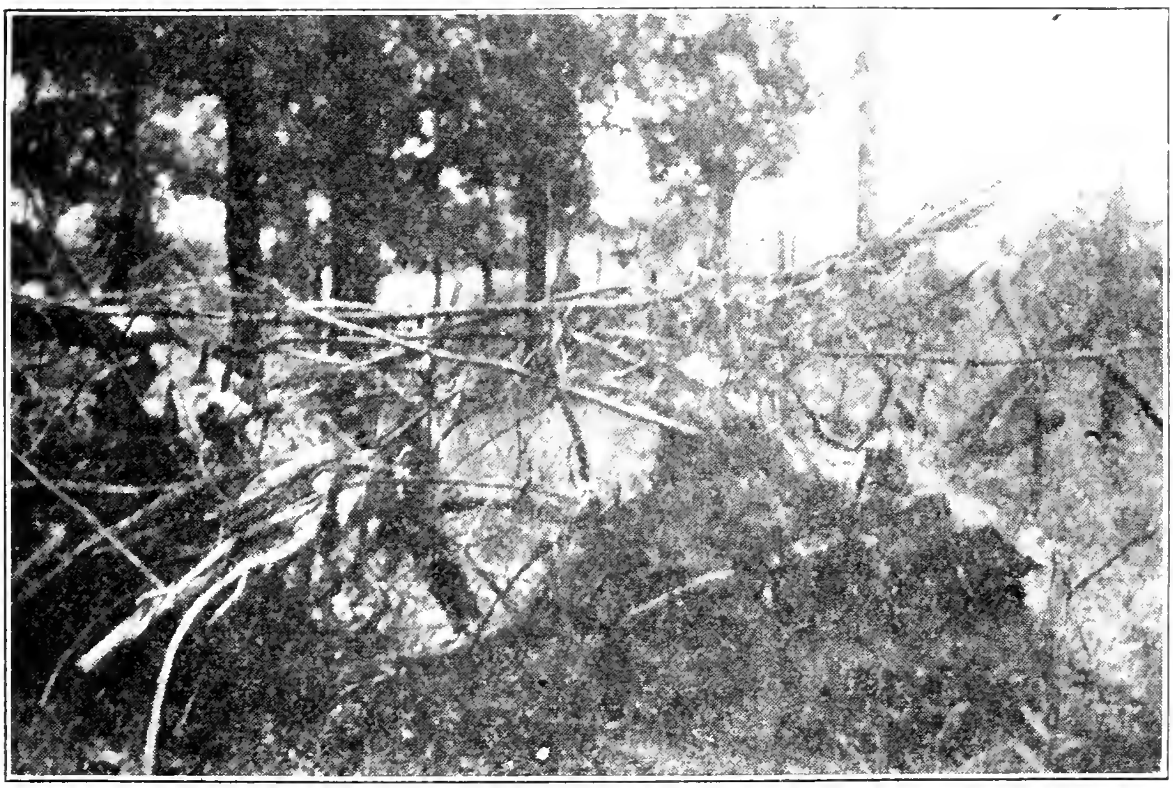


FIG. 190. *A stump fence*

Hedge fences. On prairie farms settled forty or fifty years ago neither rock nor timber was available for fence purposes, and an attempt was made to develop a fence from growing plants. Osage orange, which grows fairly rapidly and is covered with thorns, was used in the form of a hedge. The plants were raised in nurseries from the seed, and when they were about 12 inches high stems and roots were carefully trimmed and the plants packed in bundles and taken to the fence location. A strip of ground four furrows wide was then plowed, disked, and harrowed, and a furrow plowed along the middle, in which the young plants were placed 12 to 18 inches apart, the earth being drawn around them with a hoe. The plants were permitted to grow for five years, care being taken to protect them from stock and to keep down the weeds by cultivation and hoeing. After five years the main stalks were trimmed on the sides and top, cut half through at the surface of the ground, and each plant bent over the roots of the preceding one, which had been similarly treated. The main body of the fence was thus made with these stems and was about 2½ feet high. During the next growing season the young sprouts came up through and over these stems, making a very thick growth. The tops of this new growth were trimmed to the desired height and the fence was then complete, after six years of development.

FIG. 191. *A hedge fence uncared for*

Frequently the five-year-old bushes were cut off at the ground and the fence formed entirely by the thick growth of sprouts which came up around the old stumps, a year's growth being trimmed to the proper height.

A great deal of time and labor is required to secure a fence of this type. A hedge fence must be trimmed at least once during the growing season, and a better fence can be maintained for less cost by two trimmings, during each season, as the growing sprouts cut more easily when small and full of sap. When the hedge is in this condition, two men with corn knives can trim 80 rods in half a day; to cover this same distance would require practically one day's work of two men if the sprouts were permitted to get a full year's growth.

A hedge makes a very satisfactory fence for cattle, horses, and sheep. It is difficult to get it sufficiently tight near the ground to hold pigs. It does not blow down, injure stock, or deteriorate with age if properly cared for. The objections

FIG. 192. *A good hedge fence, 40 inches high, 36 inches wide on top*

are: the extent of land used, as the roots extend out 8 to 10 feet on either side and take the fertility and moisture out of the soil; and the degree of attention required each year to keep it in shape. However, if proper attention is given to it, there is no replacement cost or labor. The trimming can be done when other work is not pressing. It is questionable whether a hedge fence is any more expensive in a long number of years than any other class of fence.

Board fence. Formerly barnyard and field fences in prairie country were frequently made of sawed lumber. Boards 6 inches wide, 1 inch thick, and 12 to 16 feet long were nailed to posts set 6 to 8 feet apart. Board fences are fairly satisfactory for a time, but they are short-lived because the lumber decays and the stock rubbing against them break them down. This use of 1″ × 6″ boards gave them the nickname *fencing.*

Wire fences. The development of fencing material by means of smooth wires twisted and with short barbs inserted every 4 to 6 inches marks the beginning of wire-fence construction and has resulted in nearly all of our modern fences being some combination of wire.

A metal from which wire can be made must be ductile and be tenacious after the wire is formed. The wire is produced from a slender bar or rod of metal drawn through a die. After drawing, the wire is usually hard and brittle and it is necessary to soften it by annealing for further drawing. It is drawn by a machine which holds the dies and supplies the power. The single-block machine draws a wire of but one diameter, while in a continuous machine the wire passes from one block to another, the final diameter being produced at one passage through the machine.

POSTS

As posts are the parts of a fence that are most likely to decay first, attention should be given to their selection. Fence posts are of three kinds: wood, concrete, and metal.

Wood posts. Although there is no sharp dividing line, wood posts may be considered as of two classes, those which have a naturally long life, and those which in their natural condition last but a short time, but the life of which can be prolonged by the application of some preservative treatment. The decay of timber is caused by the work of fungi. These fungi feed on substances in the wood and destroy by the process known as rotting. In order that they may live they require, in addition to wood, heat, air, and moisture. The wood which has each of these requirements in the proportion most conducive to their growth decays most rapidly.

Durability. The life of a fence post depends upon the kind of wood, age, rate of growth, percentage of sapwood, character of soil, and the variability of moisture where it is used. Wood that is continuously under water or in a dry place does not decay. It is the change from one medium to the other that aids the decaying process. The weakest point in a post is at or immediately under the surface of the ground, where an alternate wetting and drying occurs. Frequently posts that are sound a foot under or above ground will break off at the surface. Posts that are not to be used immediately upon cutting or are to be seasoned for further treatment should be peeled and piled on other timbers placed on the ground, the posts being laid in layers at right angles to one another a sufficient distance apart to permit the free circulation of air. Bark and sapwood tend to cause rapid decay.

The average life of air-dried posts is as follows:

	Years		Years
Red cedar	30	Ash	5
Black locust	22	Maple	5
Catalpa	20	Red or black oak	5
White oak	15	Birch	4
Black walnut	15	Basswood	4
White cedar	10	Jack-pine	4
Tamarack	8	Cottonwood	4
Elm	7	Aspen	4
White willow	6		

Investigations carried on at the Ohio Agricultural Experiment Station developed the following information with regard to wood posts. Large posts usually last longer than small ones of the same wood. It makes little difference which end is put in the ground except that the larger or sounder end should have the preference. In stiff clay soil posts decay principally just beneath the top of the ground. In porous sandy or gravel soil they usually rot from the top of the soil down. Seasoning does not seem to have any marked effect on durability unless followed by some other treatment. Timber that grows rapidly and in the open is not so good as the same variety grown in the woods. Though it has not been absolutely proved, there is some evidence that just when the trees begin to grow in the early spring is not a good time to cut posts. The wood at the center of the tree is not so good as that just inside the sapwood. This is especially true of locust, cedar, and hardy catalpa. The quality of the wood or the condition of the wood fiber of the post is a very important factor in its ability to withstand decay. The poorer quality of posts and defective portions in otherwise good posts are usually somewhat darker than the normal color, especially near the center of the tree.

Preservative treatment. The life of a wood post can be prolonged by methods of treatment which will prevent the growth of fungi. A waterproof coating may be applied to the post to exclude moisture or a coating which is in itself poisonous. Either of these will tend to delay the action of rotting by interfering with the development of the fungi. Another method is to char the lower part of the post from the bottom to a point which will be about twelve inches above the surface. One way of doing this is to hold the lower end of the post over a hot fire, which will form a coating of carbon over the surface, or, more satisfactorily, to dip the end in crude petroleum and then burn off the oil. This drives the hot oil into the post, and, with the charred coating, prevents decay. Another method is to dip the seasoned post into crude oil or in coal tar or to apply a coating of either with a brush. This is not so satisfactory as the other methods.

The growth of the bacteria can be prevented by treatment of the lower part of the post with zinc chloride, copper sulphate, or bichloride of mercury. These solutions are cheap, but they are soluble in water and have little value if the posts are exposed to moisture. Heavy oils of coal tar and petroleum are not affected by moisture, and are poisonous to the fungi. Most of these oils have as a basis creosote, a by-product of coal, secured in the manufacture of illuminating gas. On account of its cheapness and the ease with which it can be secured, creosote is considered the most effective solution for the treatment of posts. The method of using it is to set up one circular tank 3½ feet in diameter and 3½ feet deep and a rectangular tank 4 by 4 by 8 feet in dimensions. The oil in the circular tank is heated to 220° Fahrenheit and that in the rectangular tank to 110°. The posts, which have been peeled and seasoned, are set upright, butt down, in the hotter oil and left for a time, depending on the species of wood. They are then submerged in the cooler oil for another period, after which they are taken out and piled to dry. The seasoning of the wood removes the water, and the peeling saves the oil which would be taken up by the bark. The bath in the hotter oil drives out much of the air, so that the cooler oil is drawn into the wood as the air which still remains contracts. Oak, cottonwood, willow, and pine take this treatment very readily. Basswood, maple, and birch receive only a slight penetration. All species treated are of equal durability. The cost of the treatment in 1913 was from 10 to 15 cents, and a post made of wood which would cost 8 cents could be made to have a life of twenty years at a total cost of 20 cents if treated at a cost of 12 cents.

Setting wood posts. Posts should be selected which will last as long as the wire which is placed upon them, as the full efficiency of the wire will not be secured when it is necessary to restretch it on the posts. The size of the posts and the distance apart which they should be set are determined by soil conditions, the nature of the fence, and the judgment of the individual constructing the fence. For a temporary barbed-wire fence, 3-inch posts 2 rods apart give satisfaction. For a permanent fence the customary distance between posts is usually a rod. A post 4 inches in diameter at the smaller end is considered of minimum size, but many landowners use posts as large as 5 and 6 inches at the smaller end. The length of the post will depend upon the height of the fence and the depth the posts are set in the ground. The length should be such that the top of the post will be approximately 6 inches above the top wire of the fence.

Posts are usually set 2½ feet into the ground. When the ground is full of moisture, the post may be sharpened and driven, and by this method a line of posts may be set very rapidly. The posts are sharpened and laid in a wagon

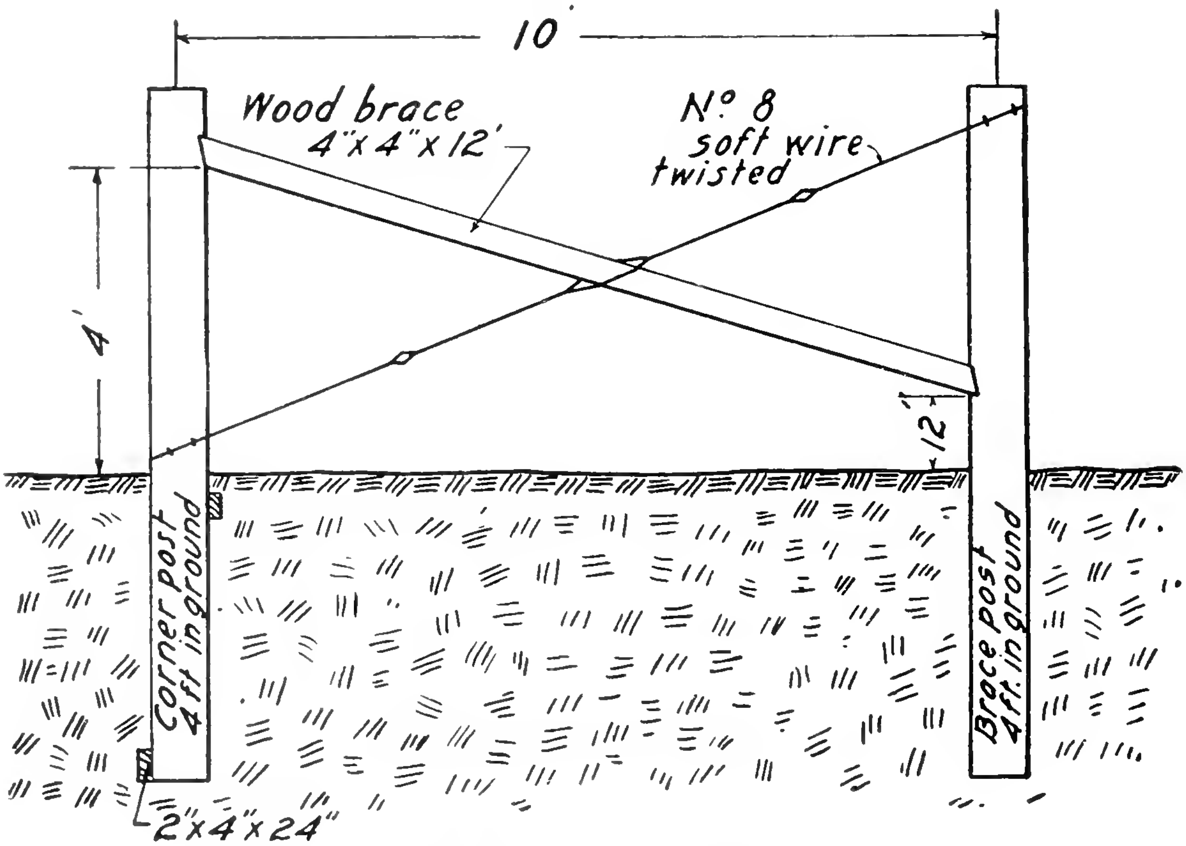


FIG. 193. *Method of bracing corner or end posts*

and the wagon driven along the line on which the posts are to be set, the posts put in place, and driven from the rear end of the wagon. A driven post does not stand solidly, and more or less injury is done to the upper end by driving. This method is suitable only for temporary fences. There are various tools on the market for setting posts by digging, known as "post-hole augers" or "post-hole diggers." The variety used will depend upon the soil, as one satisfactory in clay would not be in sand.

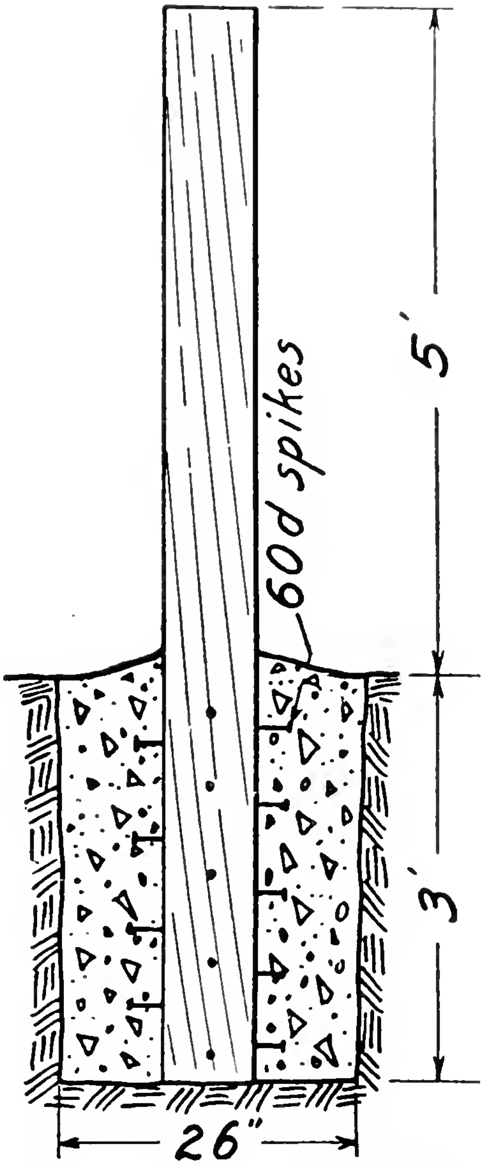


FIG. 194. *Method of bracing posts by the use of concrete*

The rate at which posts can be set by digging is dependent upon the hardness of the ground, the depth to which the posts are set, the ability of the man doing the work, the topography of the land, and the distance apart of the corner and gate posts. In dry hard soil four posts per hour for one man is the limit. In easy digging sixteen posts per hour can be set. It is generally estimated that eight posts per hour is a fair average under ordinary farm conditions.

Corner posts. A post set as described is satisfactory for a line post, but it does not have sufficient rigidity to serve as a corner post. For a permanent fence the corner posts, posts at the end of each 40 rods in a straight line, and gate posts should have a ground anchorage and top bracing as shown in Figure 193. The corner posts should not be less than 6 inches in diameter at their smaller end, and 8-inch posts are preferable. They should extend into the ground from 3 to 4 feet. The posts should be set long enough before the construction of the fence to permit the earth around them to settle and become solid. The best time of the year is after the frost has left the ground in the spring. The brace timbers used should be 4 by 4 inches by 12 feet, and the ends should be spiked to each post with two 60-penny spikes. Wire braces should be two strands of No. 8 soft wire twisted together.

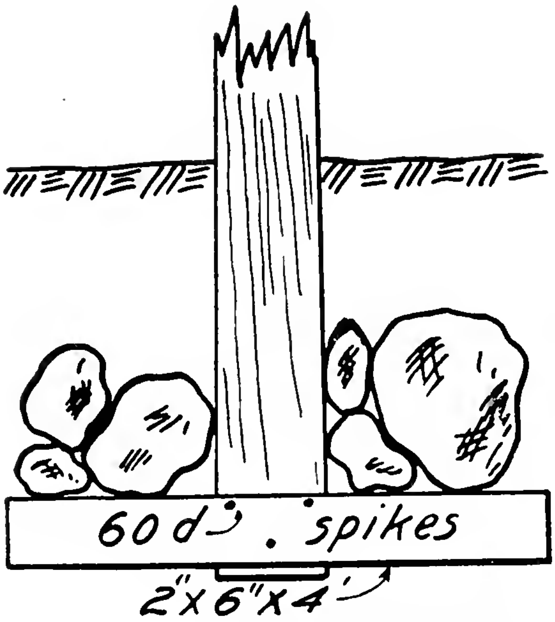


FIG. 195. *Method of anchoring posts on low depressions where there is a tendency for the wire to pull the post out of the ground*

Concrete posts. The rapidity with which wood posts decay and the increasing cost of timber have led to the use of some other materials for posts. Concrete posts (Fig. 196) are of two kinds, solid and hollow. The only object in making a post hollow is to save material and decrease weight. The hollow posts are the more expensive, because additional time is required in fitting an inside form and in arranging the reinforcement. There is some question as to their durability as compared with solid posts. Solid posts may be made with a dry mix tamped into the mold or with a wet mix poured. The mold should not be removed in either case until the post has cured sufficiently to stand handling. With a wet mix, one post a day is all that can be made in a mold. The best mix is 1:2:3, thoroughly mixed. The reinforcement should be placed approximately three-quarters of an inch from the surface. The reinforcing material should be sufficiently rough to form a bond with the concrete. In using smooth, cold-drawn wire, it has been found to be an advantage to wash it with a strong caustic solution or to treat the wire with a diluted solution of salammoniac, which slightly rusts it.

Concrete posts are permanent when well reinforced and the reinforcement is so placed that the strain will come upon it before the concrete breaks. On account of the weight more time is required to set concrete than wood posts. The post must be well set in the ground, for its weight will tend to pull it over if it gets out of plumb. The agricultural experiment station of Colorado conducted an elaborate set of experiments with concrete posts, from which the following conclusions were drawn: Poured posts are easier to make than tamped ones, but are more expensive because one mold will make but one poured post per day.

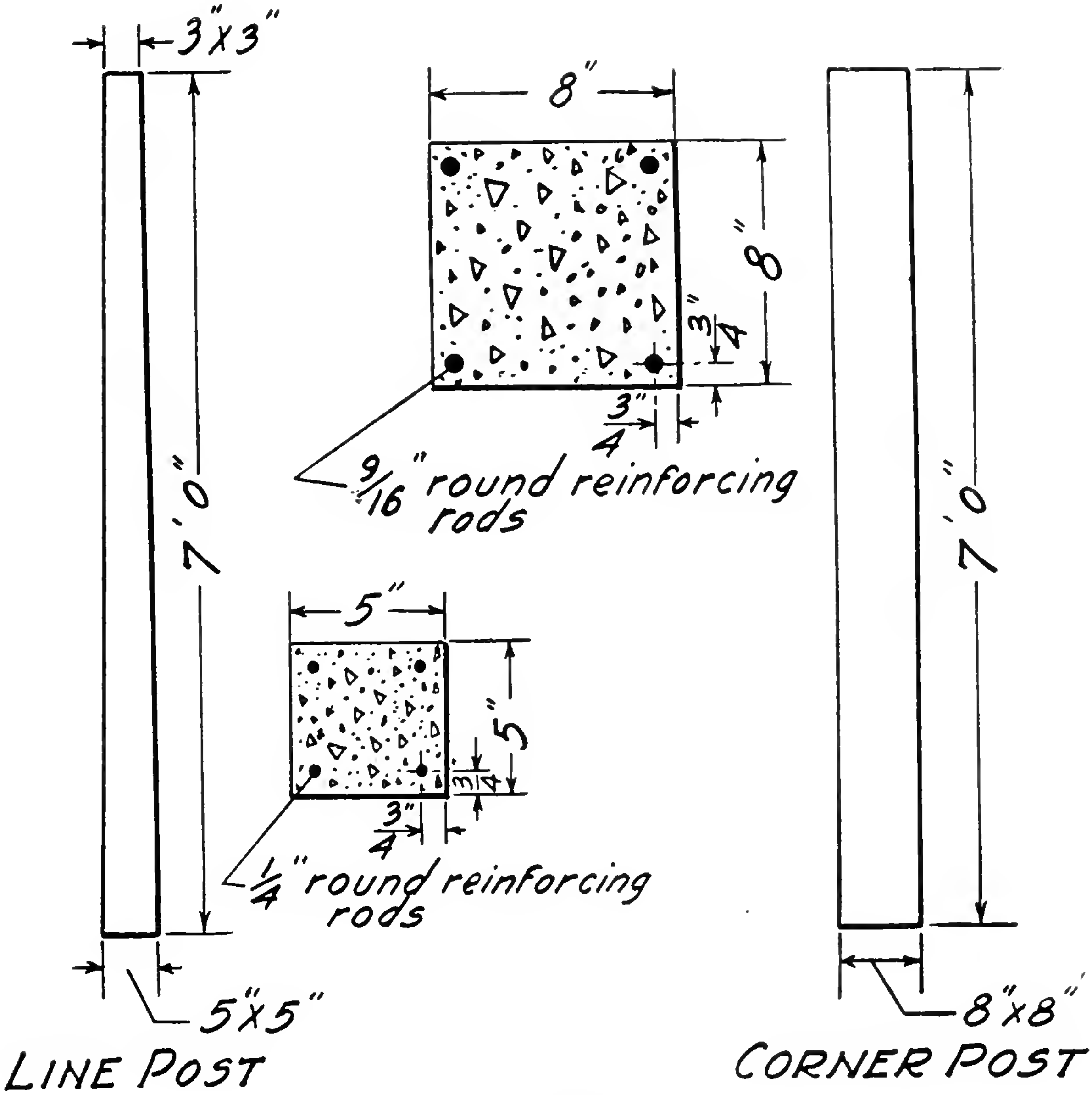
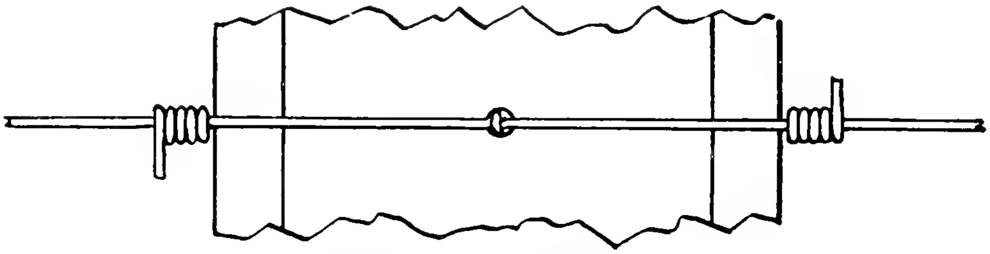
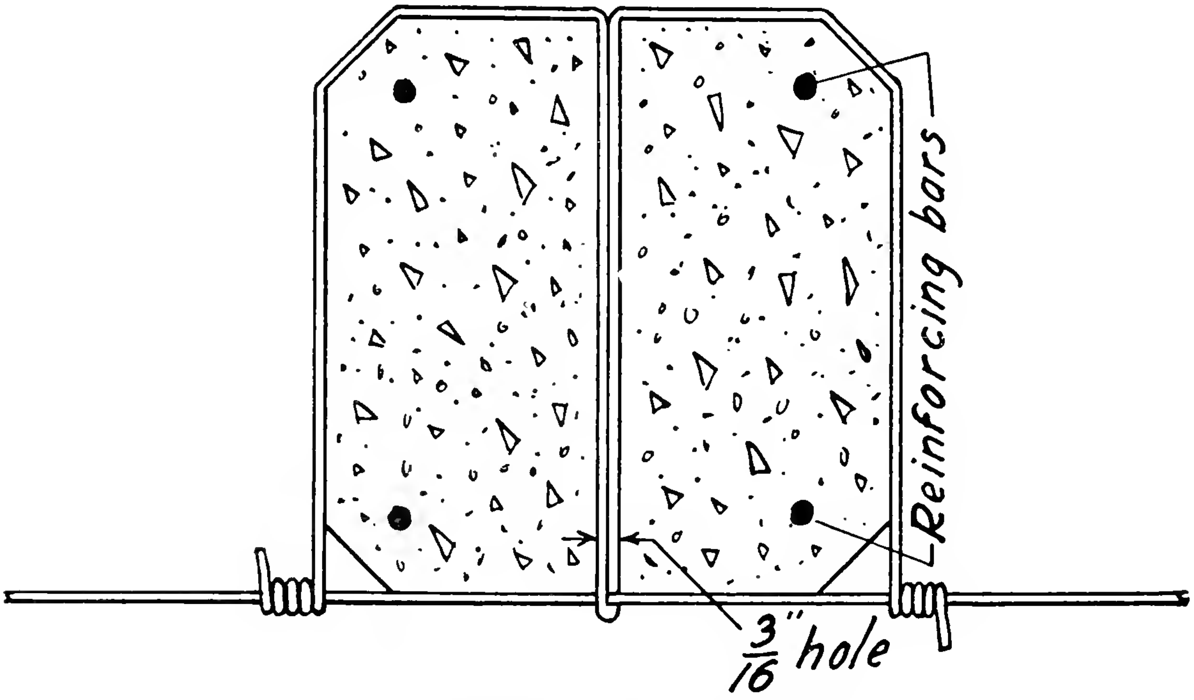


FIG. 196. *Concrete fence post*

Poured posts are 25 per cent stronger than tamped ones of the same size, mixture, and reinforcement. The poured post is enough better in every respect to justify its construction and use in preference to tamped posts. The best form of post is one which is equally strong from all directions. Square or round posts fulfill this requirement. The most



ELEVATION



CROSS SECTION

FIG. 197. *Method of attaching line wire to concrete posts*

economical post is one in which the size from the lower end to the surface of the ground is the same and the post tapers from the ground line to the top. The reinforcement should be strong, light, and of sufficient roughness to permit the mixture to get a firm grip upon it. Two or more wires twisted together make a satisfactory reinforcing material. Concrete posts should be piled in the shade for at least sixty days, and for the first thirty should be sprinkled daily.

Wire attachment. There are several methods used for attaching the line wires, but the method usually preferred is the following (Fig. 197): A tie-wire in the form of a long staple is straddled over the line wire and both ends passed through a hole left in the post. An end is then brought to either side of the post and twisted around the line wire.

This system insures a solid fastening, and, in case the tie-wire breaks, another can be put in place. If holes have not been left in the post, the tie-wire should be looped tightly around the post, and the end twisted around the line wire.

Metal posts. Posts of iron or steel (Fig. 198) are used to some extent for farm fences. They can be made light and are easy to set in the ground. In loose soils they are hard to keep in place unless concrete is poured around them. They may be bent or broken off by stock shoving against the fence, though this objection can be overcome by proper construction and if the wire is kept taut. The price of iron and steel posts in the past has been such as to prevent their general use on the farm. The advantages of metal posts are the ease and rapidity with which they can be set and the fact that they serve to ground electric currents and thus tend to lessen the danger to stock from lightning.

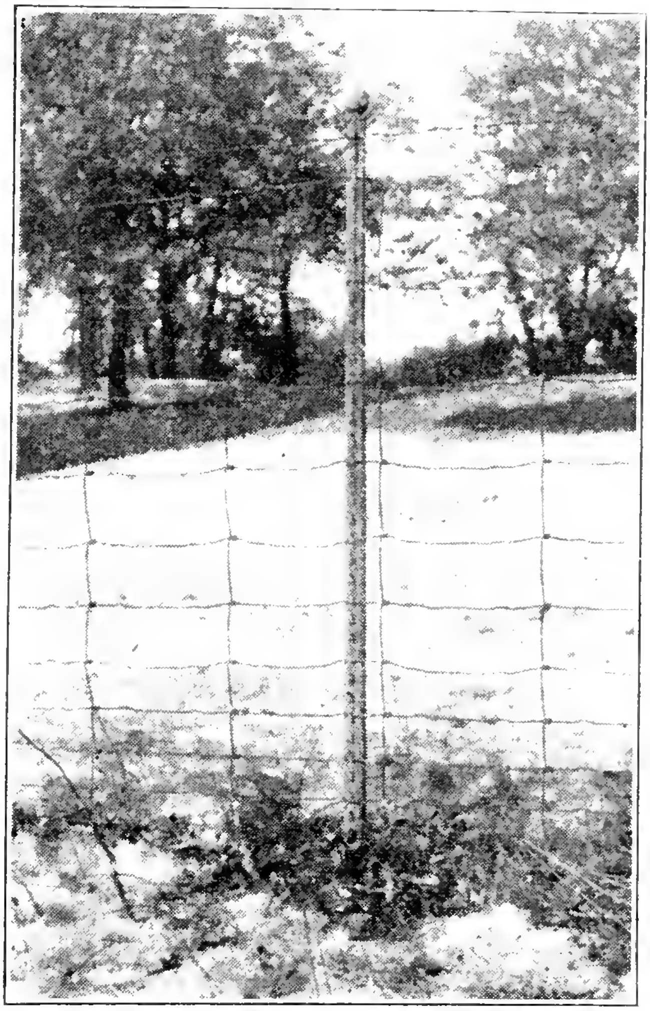


FIG. 198. *A steel fence post*

WIRE FENCING

Height. The proper height of a fence varies with the kind of stock to be inclosed and the individual preferences of the landowner. On ranch lands in the West three barbed wires at a maximum height of 42 inches are used, although a height of 48 inches is more desirable. The wire must extend close enough to the ground to prevent the smallest inclosed animals from crawling under and should be high enough to prevent the largest from jumping over. A barbed wire placed along the top of any class of fence (Fig. 199) is desirable unless the fence is of such height that an animal cannot reach over it with its head. Some fence builders recommend placing a barbed wire close to the ground when the main part of the fence is made of woven wire, the object being to prevent animals from crawling under the fence. The spacing should be such that animals cannot insert their heads between the wires. The spacing between barbed wires can be considerably greater than between smooth wires, since the barbed wire will not have so great a strain, the barbs preventing the stock from

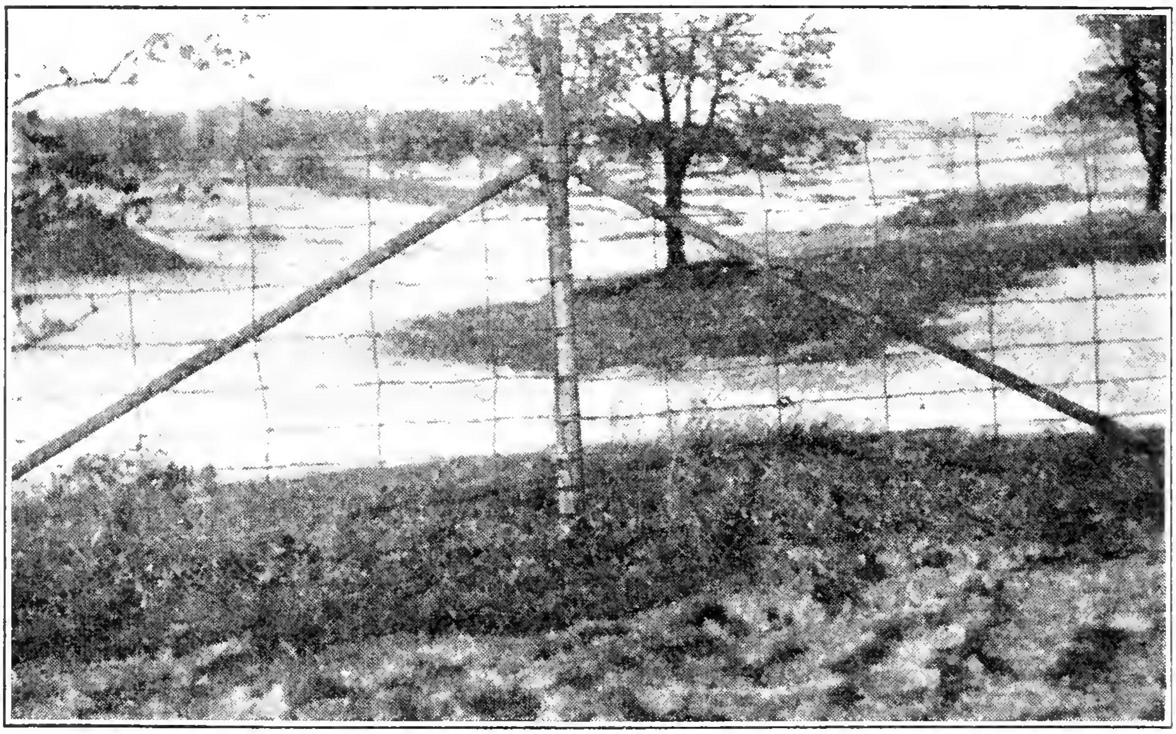


FIG. 199. *A braced steel line post in a woven wire fence with one barbed wire on top*

pushing against the fence. In woven wire the spacing varies slightly with the different manufacturing firms. A fence in which the spacing is considered approximately correct is as follows: woven wire beginning with the ground, 3 inches, 3½ inches, 4 inches, 4½ inches, 5 inches, 6 inches, 7 inches, and then 7 inches to a barbed wire and 8 inches to another barbed wire.

Commercial lengths and weights. The wire used should be thoroughly galvanized, resilient, and of a sufficient degree of toughness to splice without breaking. A hard-drawn Bessemer steel wire is the quality ordinarily used. Galvanized wire should be clean and bright when purchased and should be stored in a dry clean place until used. Barbed wire is purchased in rolls or spools of from 80 to 90 rods per roll. The weight is approximately a pound per rod. Since the same diameter of wire is not always used, the weight may be as much as 1¼ pounds per rod. Woven wire comes in rolls of 20 rods each. The weight will vary somewhat with the gauge, but the following is the approximate weight for the various widths of wire:

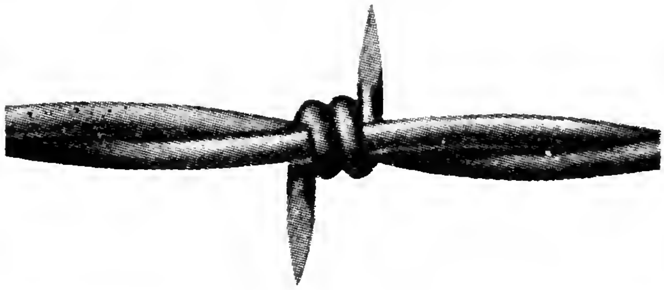


FIG. 200. *Two-point barbed wire*

55-inch	10 3/10 pounds
47-inch	9 1/10 pounds
39-inch	8 1/10 pounds
32-inch	7 2/10 pounds
26-inch	6 3/10 pounds
20-inch	5 5/10 pounds

It has been learned by experience that the durability of a fence depends upon the size of the wire used, the use of a heavy wire being the more economical. No. 9 is considered the most satisfactory from the point of service and of economy in durability. Data collected and published by the United States Department of Agriculture in *Bulletin 321* give the life of a fence made of No. 9 wire as twenty-one years, and of one made of No. 12 wire as twelve years. The same bulletin also cites statistics to show that the higher woven wire fences are more durable than the lower ones. These statistics would indicate that the high heavy woven-wire fence is more economical than the narrow light woven-wire fence, although the light wire is cheaper in first cost.

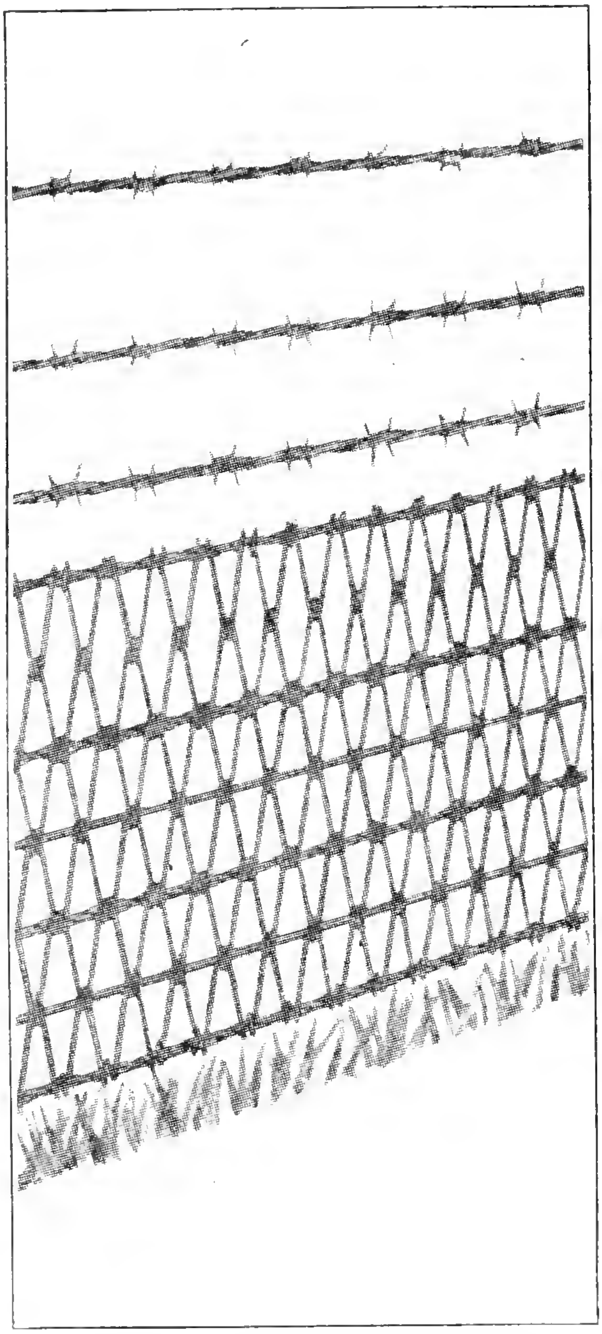


FIG. 201. *Twenty-six-inch woven-wire ribbon, with three barbed wires above*

Staples. With either barbed wire or woven wire, staples (Fig. 202) are used for attaching the wire to the posts. For hardwood posts the length is 1¼ inches and for soft wood 1½ inches, although other sizes are manufactured. Staples are sold by the pound, the number per pound varying somewhat with the manufacturers. The following is the approximate number per pound:

1-inch	128
1⅛-inch	116
1¼-inch	104
1½-inch	89
1¾-inch	78

Staples should be driven at an angle with the grain so that the two points will not enter the same grain and cause a crack from which the staple may be easily pulled.

Erection. Both barbed wire and woven wire are distributed by being unrolled from the rear end of a wagon, or woven wire may be rolled along the ground and the barbed wire unrolled by means of a crowbar placed through the center of the spool so that two men can carry it.

Splices should be made when the length of the roll does not reach to a corner post to which the stretcher is attached. Sixty to eighty rods usually make a sufficient distance for proper stretching of barbed wire, although under favorable conditions of level ground and a powerful stretcher a half-mile can be stretched at one hitch. There are various forms of commercial stretchers on the market that give satisfactory results, and if much fencing is planned a commercial stretcher is desirable. A block and tackle can be used, and very satisfactory work may be done if the axle of a wagon is blocked up until one of the rear wheels is free from the ground and one end of a piece of smooth wire is attached to the fence wire and the other end to the hub of the wheel. Sufficient tension can be given the fence wire, when the wheel is turned, so that the smooth wire will wind around the hub. For stretching woven wire, the stretcher must be attached to the wire by some device which will bring a uniform strain on all of the horizontal wires. When either woven wire or barbed wire is fastened to a corner post, the ends of the wire should be wrapped around the post and twisted back over themselves.

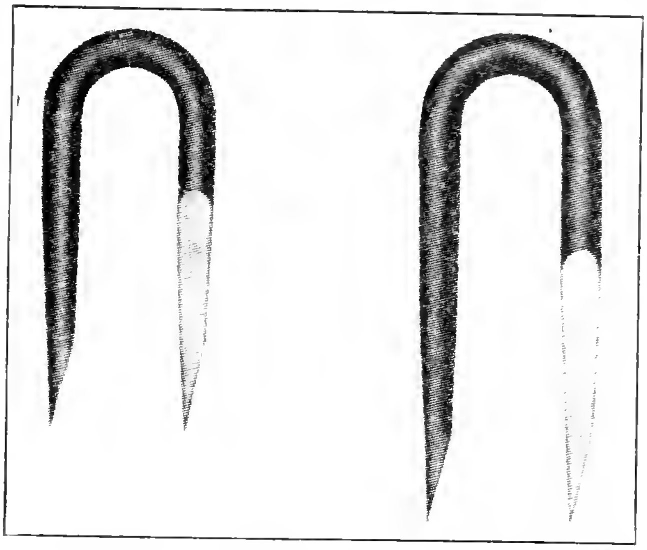


FIG. 202. *Fence staples 1¼ and 1½ inches long*

Wire should be stretched as tight as possible within reasonable limits. When the wire is being stretched over uneven ground, a man should walk along the line and lift the wire from the ground in places where it strikes, so that the tension will be even throughout the entire length. All horizontal wires should be stapled at every post, but the staples should not be driven so far that they kink or push the wire into the post. Manufacturers of woven wire publish catalogs in which they give complete descriptions for placing corner posts and stretching their materials. Such instructions should be followed by the purchaser, due allowance of course being made for the local conditions.

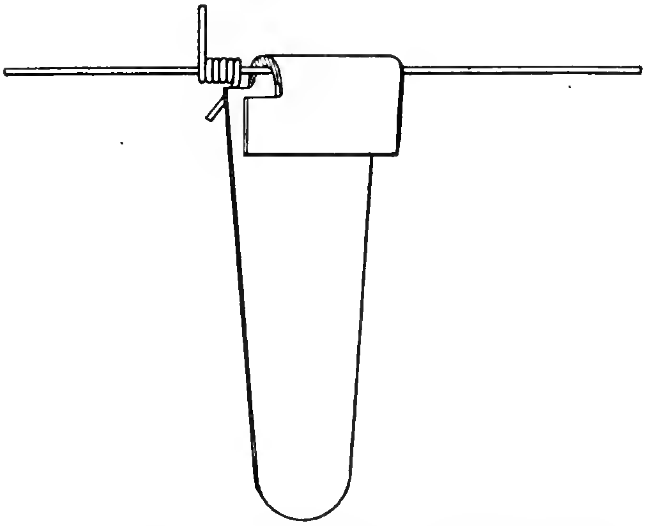


FIG. 203. *A wire splicer that can be made from one-half of a strap hinge*

Temperature effects. The tension of the wire is affected by changes of temperature. A straight wire stretched very tight in hot weather is liable to break in cold weather, and if stretched in cold weather may become slack in hot weather. This condition is overcome in the manufacture by the method of slightly springing or coiling the wire so that the spring adjusts for temperature.

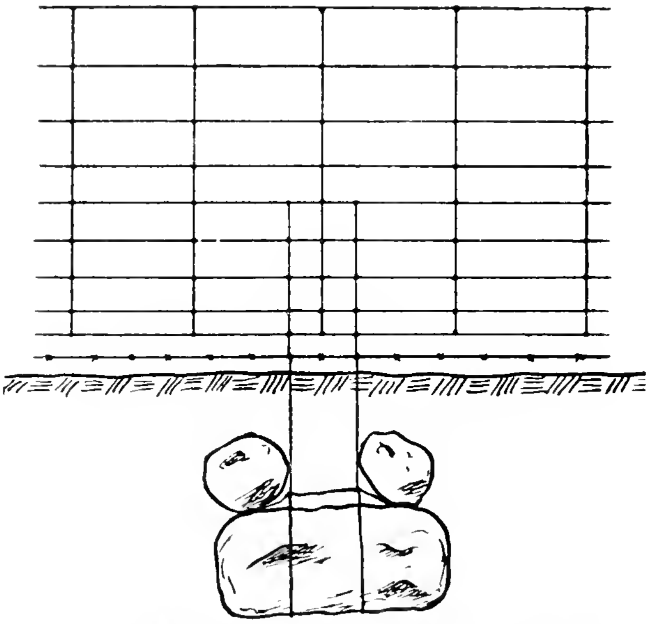


FIG. 204. *Method of anchoring the wire to the ground in depressions*

Inspection. After a fence is completed, it should be inspected at regular intervals, loose wires tightened, and staples that may have pulled out replaced.

All-purpose fence. After the posts are set, the variety, height, and spacing of the wire will depend upon the kind of stock to be inclosed. If an all-purpose farm fence is required, the following is recommended: next to the ground a 26-inch woven wire; above this three galvanized barbed wires at a height of 30, 38, 48 inches, respectively. This fence, if well constructed, will turn any farm animals except poultry and with very little labor will last as long as the posts remain sound.

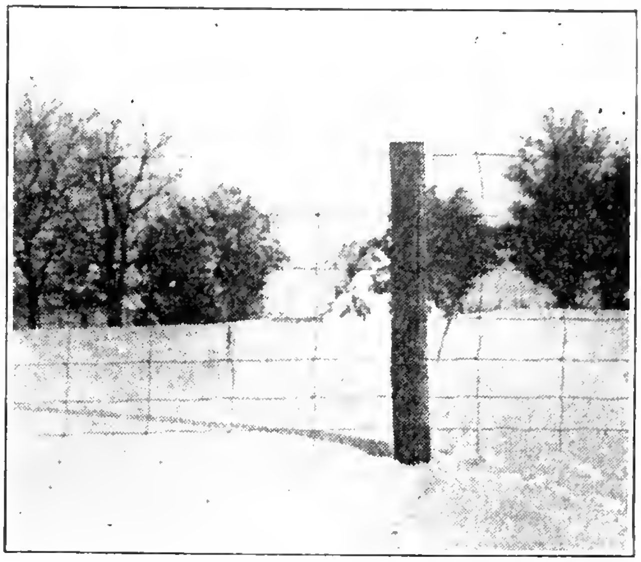


FIG. 205. *A wooden line post in a woven-wire fence*

Typical fences which have given satisfaction from the standpoint of cost and service are as described below and on page 242.

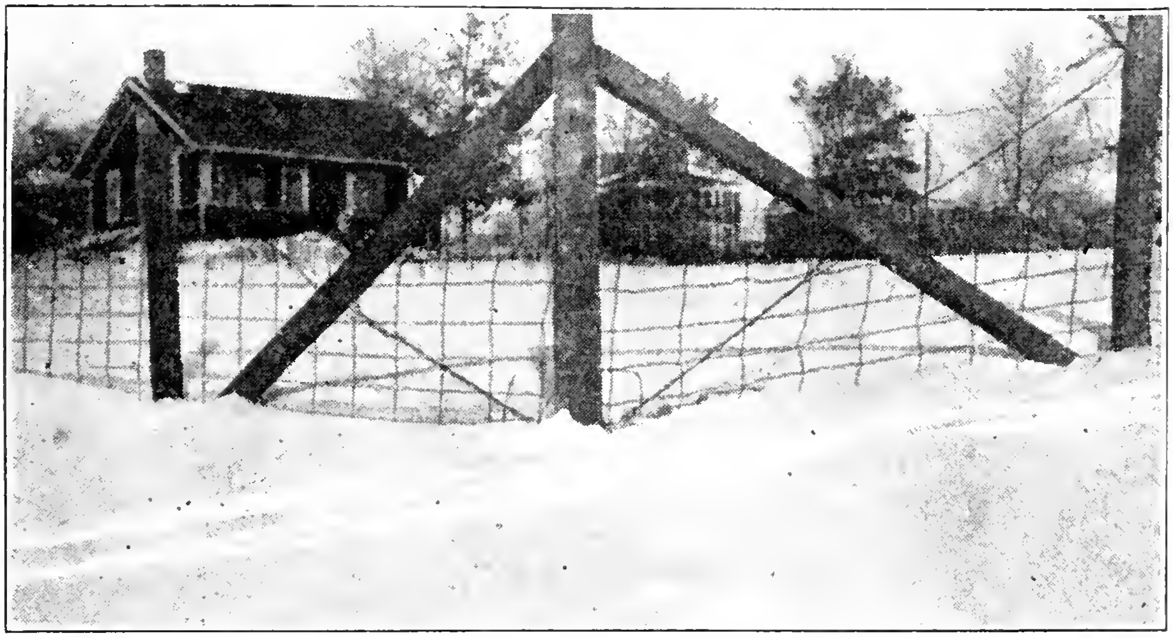


FIG. 206. *A corner post in a woven-wire fence.*

Four-inch posts set 1 rod apart, woven wire next to the ground 26 inches high, barbed wire 30 inches high, barbed wire 42 inches high.

A farm fence for all kinds of stock: Line posts of Osage orange, 8 feet long and 8 to 10 inches in diameter, barked and seasoned, set 3 feet deep in a hole dug large enough to allow 14 inches of concrete on all sides of the post; corner posts the same except 9 feet long and set 4 feet deep; small stones used for filling in with concrete. The concrete furnishes rigidity without the use of braces. The posts are set 16 feet apart and the wire put on after the concrete is dry enough to stand the strain. Woven wire is used along the ground 39 inches high; a barbed wire 43 inches high; a barbed wire 49 inches high, and a barbed wire 57 inches high. Staples 1½ inches long, not driven tight so that the fence can give its entire length, are used. The ends of the wire are wrapped around the posts and tied back on themselves.

Fence for horses and cattle. For horses and cattle a 48-inch woven wire and a barbed wire 5 to 6 inches above make the best fence. Such a fence is rather expensive, but it avoids any danger from wire injuries to the stock. A much cheaper fence can be made by the use of three wires, the lower wire being smooth and placed 22 to 24 inches from the ground. Nine or 10 inches above this a barbed wire should be placed, and 10 or 12 inches higher another barbed wire.

A better combination, however, is to place a smooth wire 18 inches above the ground, 8 inches above this a barbed wire, 8 inches higher another barbed wire, and 10 inches higher a third barbed wire. Such a fence as this is sufficient and much cheaper than woven wire the same height, but it does not remove the danger of serious injury to animals, particularly horses. Another combination is to use 34-inch woven wire next to the ground, 5 inches above this a barbed wire, and 8 inches above this a second barbed wire. Yards and pastures which are made to retain horses kept for breeding purposes should be inclosed by the best 60-inch woven wire fence.

Temporary fences. For temporary fences two barbed wires are frequently used, the lower one being placed 26 inches above the ground and the second one 38 inches from the ground. So long as pasture is good, such a fence will turn horses and cattle, but there is a tendency, as pasture gets poor, for an animal to attempt to crawl under or between the wires, with the result that all of the stock break out and possibly some one of them is badly cut. In a temporary fence the wires should be placed on the inside to prevent the animal from pulling out the staples by pushing against the wire.

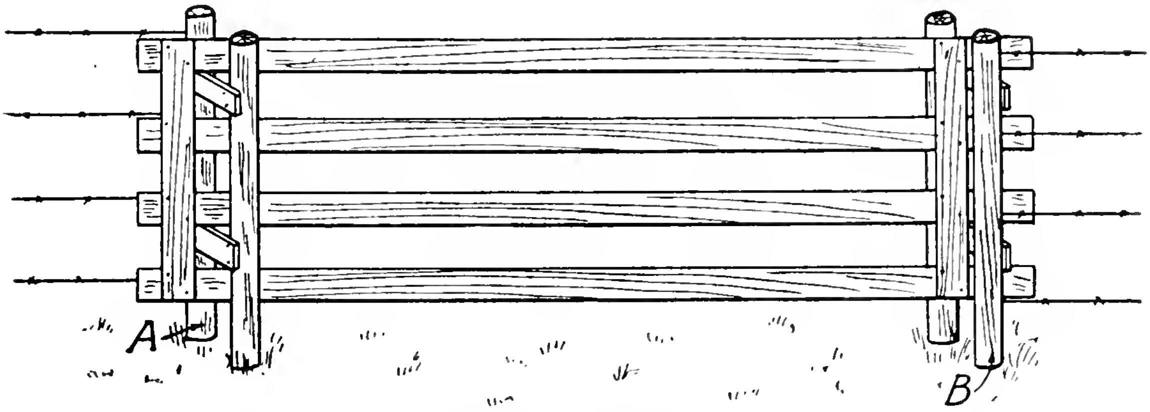


FIG. 207. *A cheap and convenient farm gate. Posts A and B should be braced as shown in Fig. 193.*

Fence for hogs and sheep. For hogs and sheep a 34-inch woven-wire fence with a barbed wire 5 inches above and a second barbed wire 15 inches higher is desirable. A lower fence can be used, but there is a tendency for hogs to climb on the fence and break it down. Twenty-six- and 30-inch woven wire have been tried out, but have not always been found satisfactory.

Cost of fencing. *Bulletin 321* of the United States Department of Agriculture gives the following data relating to fence construction: This table (page 244) shows the length of fence which two men can build in a day under ordinary conditions. The posts are set at an average depth of 32 inches and the corner and end posts are placed approximately 40 rods apart. Wages are considered at 15 cents per hour. The posts are placed at the distance indicated at the head of the columns, and estimates are given for posts driven and posts set.

KIND OF FENCE	DISTANCE APART OF POSTS							
	12 Feet or Less	13–16½ Feet	17–24 Feet	25–37 Feet	12 Feet or Less	13–16½ Feet	17–24 Feet	25–37 Feet
	DAY'S WORK				LABOR COST PER ROD			
	Rods	Rods	Rods	Rods	Cents	Cents	Cents	Cents
BARBED WIRE								
2 strands:								
Post driven	......	89.5	95.0	166.9	......	3.4	3.2	1.8
Posts set	58.7	71.5	75.0	121.5	5.1	4.2	4.0	2.5
3 strands:								
Posts driven	64.0	89.1	116.4	156.0	4.7	3.4	2.6	1.9
Posts set	43.7	58.7	68.3	95.4	6.9	5.1	4.4	3.1
4 strands:								
Posts driven	76.6	83.2	92.4	95.0	3.9	3.6	3.2	3.1
Posts set	39.3	47.9	50.6	70.8	7.6	6.3	5.9	4.2
5 strands:								
Posts driven	52.2	56.7	70.9	100.0	5.7	5.3	3.8	3.0
Posts set	25.3	34.1	38.7	46.2	11.8	8.8	7.7	6.5
6 strands:								
Posts driven	29.5	56.7	67.5	....	10.2	5.3	4.4	....
Posts set	19.4	26.4	32.0	34.1	15.4	11.3	9.4	8.8
NARROW WOVEN WIRE with 2 or more barbed wires:								
Posts driven	48.7	53.0	74.1	89.8	6.2	5.7	4.0	3.3
Posts set	26.3	33.0	37.9	47.1	11.4	9.1	7.9	5.5
WIDE WOVEN WIRE with 1 barbed wire:								
Posts driven	50.9	55.3	77.2	94.2	5.9	5.4	3.9	3.2
Posts set	27.2	33.9	39.9	49.7	11.0	8.8	7.5	4.6
WIDE WOVEN WIRE without barbed wire:								
Posts driven	61.3	65.4	80.2	108.5	4.9	4.6	3.7	2.8
Posts set	30.6	39.0	45.8	56.7	9.8	7.7	6.6	5.3

The following cost of constructing 40 rods of fence with hired labor will give an idea of the materials needed and the time spent at the various operations. Individual cost will vary with the location.

Cost of setting 40 rods of 52-inch fence with hired labor: 8-foot posts 5 inches in diameter at the smallest end, spaced 20 feet at the centers, set 3 feet deep, 2 anchor posts 9 feet long, 9 inches in diameter at the smallest end, set 4½ feet deep. Posts were set by means of taking off 1½ feet with a spade and then digging with a post-hole auger. Anchor posts were dug all the way.

32 posts at 25 cents	$8.00
2 end posts at 50 cents	1.00
2 braces 4″ by 4″ by 12′ at 25 cents	.50
2 anchor braces at 25 cents	.50
40 rods woven wire at 47 cents	18.80
5 pounds staples at 3½ cents	.17
Wire for braces	.13
12 hours digging post holes at 25 cents	3.00
5 hours setting posts at 25 cents	1.25
5 hours stringing wires at 35 cents	1.75
5 hours stringing wire at 20 cents	1.00
Total cost	$36.10
Cost per rod	$0.90¼

The cost of 80 rods of 26-inch woven-wire fence with three barbed wires was as follows on a Minnesota farm:

	Total Cost	Cost per Rod
4-inch posts set 1 rod apart, at 10 cents	$ 7.80	$0.097
Digging holes and setting posts at 15 cents per hr.	1.50	.018
Two corner posts, one center post with anchor posts, corner braces set	1.50	.022
Staples, 6 lbs. at 5 cents	.30	.003
Woven wire at 35 cents per rod	28.00	.35
Barbed wire, 3 rolls at $3.50	10.50	.131
Stretching and stapling at 15 cents per hr.	3.00	.037
Use of team at 15 cents per hr.	1.00	.012
	$53.60	$0.670

The cost of 80 rods of fence of 32-inch woven wire with two barbed wires above, all other conditions the same, was 67 cents per rod.

The cost of 80 rods of 39-inch woven-wire fence with one barbed wire above and one at the bottom to hold hogs, all other conditions the same, was 71 cents per rod.

Eighty rods of three-strand barbed wire fence, all other conditions the same as above, cost 30 cents per rod.

Eighty rods of temporary fence, posts set 2 rods apart, two strands of barbed wire, cost 20 cents per rod.

Eighty rods of fence of 26-inch woven wire, with three barbed wires, posts 1 rod apart, cost 58 cents per rod.

Eighty rods of fence of 28-inch woven wire, with three strands of barbed wire set 1 rod apart, cost 53 cents per rod.

Eighty rods of fence of 26-inch woven wire, posts set 2 rods apart, cost 39 cents per rod.

One hundred and eight rods of temporary hog fence of 26-inch woven wire set 2 rods apart cost 38 cents per rod.

SUMMARY

Fencing is one of the necessary improvements on all farms, and the fence should always be well constructed and well maintained. The material of which a fence is constructed will depend upon the locality. The spacing of the wire and the height of the fence will depend upon the kind of stock to be inclosed. The life of a fence depends upon the material of which it is made. The life of a wooden fence post depends upon the conditions of the soil and the nature of the wood. By proper treatment poor post wood may be made as lasting, for the same cost per year, as good post wood. Fence material should turn stock without injuring them. A temporary fence made of driven posts and two or three barbed wires has been used with satisfaction, but there is always danger of stock breaking through and of serious injury to cows and horses. A good fence is one which holds the stock and costs the least in original construction and in maintenance. A fence that is cheap in first cost may be expensive because of high maintenance cost. Materials and methods of constructing a fence are largely controlled by local conditions and individual preference.

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CHAPTER XIII

IRRIGATION

Definition. *Irrigation* is the artificial application of water to land for the purpose of promoting vegetable growth. While generally thought to have been developed in modern times, it was practiced in Egypt from 2000 to 1000 B.C. It has been employed in this country as an adjunct to agriculture for about seventy years and has been extensively developed in the past thirty years. Until recently irrigation has been limited generally to the arid and semiarid regions, but it has been found beneficial to certain classes of crops in the humid regions, and each year witnesses an increased development among gardeners and fruit growers. In fact, its application where rainfall is heavy is more general than might be supposed on first thought. In the western states any sprinkling or watering of plants is considered irrigation, but in the eastern part of the country it is not the custom so to designate the watering of gardens and lawns with pails, hose, and various mechanical sprinklers.

Importance of water. Water is essential for plant growth. It is taken in through the roots, circulates through the plant vessels, and is evaporated from the leaves or built into tissue. It serves three purposes: first, as a direct food for the plant either as water contained in the soil or by breaking up into hydrogen and oxygen and being used in new compounds; second, as a transporting medium which carries food from the soil and air to the point of assimilation in the plant; third, as a regulator of the physical condition of the plant. The quantity of water used by a crop is very large, from 200 to 500 pounds being necessary for the production of 1 pound of dry matter. From 60 to 90 per cent of the weight of all staple crops is due to water. When there is not sufficient water, the plant suffers, its growth is stunted, seed sets too early, vitality is weakened, it becomes less able to resist the attack of fungi and insect enemies, and in extreme drouth it dies.

Value of irrigation. This method of supplying plants with water should be regarded as an important phase of agriculture. It is an effective means of soil improvement, and without it the use of fertilizers and cultivation in a dry country are of little value. The practice is not limited exclusively to any one part of the country, and, while it has been used more extensively on the Pacific than on the Atlantic coast, it has been found profitable in the East and Southeast. Even in a country of abundant rainfall not a season passes without a period in which additional yields could be secured if there were some means at hand to supply water to the growing crop at the critical time. As intimated in the chapter on climatology, there may be need of irrigation in regions of heavy rainfall if it is largely concentrated in certain periods.

Need of irrigation. The need of irrigation depends upon the character of the soil, nature of the crop, exposure to winds at certain seasons, period of time at which the rain falls, temperatures, and method of cultivation. Coarse sand or gravel soils dry out much more rapidly than heavy clay soil. A reasonably deep soil underlaid with a retentive subsoil does not dry so quickly as a shallow one underlaid with hardpan or coarse open strata. Shallow-rooted crops are affected by lack of rain in a shorter period than deep-rooted crops, as the deeper the roots extend into the soil, the more opportunity they have for reaching moisture. Areas that are subject to dry warm winds lose surface moisture by evaporation more rapidly than unexposed areas. The proper cultivation of the surface of the soil, which forms a dust mulch, preserves the water content of the soil by lessening evaporation. The time of year at which the fruit is formed or ripened or the main growth of the plant occurs has a direct bearing on the quantity of water needed. It has been found that there are wide differences in the requirements of different kinds of fruit trees and in the early and later varieties of the same fruit. Citrous trees require more water than trees which shed their leaves a part of the year. Olive trees will bear fruit with less water than peach trees, although the olive retains its leaves much longer than the peach. Old trees that are bearing heavily usually require more moisture than young ones. Shallow-rooted vegetation may die from drouth, while deep-rooted plants will produce a fairly good crop. Tonics, fertilizers, fungicides, and insecticides are sometimes applied to trees to stimulate their growth, when the only requirement is water. Drying due to lack of water frequently gives the tree the appearance of having been attacked by some disease, and this condition may prevent proper bearing the following year.

Humid climates. Climates that have an annual rainfall of 20 inches or more are considered humid. If this rainfall is evenly distributed throughout the growing season, there will not be any need for irrigation, but the rain usually comes intermittently, and during the summer rather long periods may intervene between showers, which will check plant growth. It is not so much the quantity of rain that falls, but the time when it falls, that determines the need for irrigation. In Florida, where there is an annual rainfall of 60 to 70 inches, irrigation has been practiced extensively and the demand for it is increasing. The same is true of other states along the Atlantic coast. While the application of water may not be necessary every year to prevent crop failure or injury to plants, the fact that it is available is a guarantee against loss, for a lack of water at the critical period may greatly reduce the profits from truck and fruit and affect not only the quantity of the product, but the quality as well. While irrigation in the humid states has not been found practicable for field crops, it more than justifies its cost in gardens and on fruit farms.

Drouth. A drouth may be said to occur whenever the precipitation in any fifteen-day period falls below 1 inch. Milo Williams, in a report prepared from the Weather Bureau records, gives the following data for the years 1900 to 1909 inclusive, showing the number of periods of fifteen days or more with less than 1 inch of rainfall and the total number of days that the drouth extended beyond the fifteen-day period.

Station	Average Annual Rainfall	Number of Fifteen-Day Periods or Over with Less than 1 Inch Rainfall	Number of Days When Irrigation Was Required
Ames, Iowa	30.39	23	190
Oshkosh, Wis.	29.78	27	292
Vineland, N. J.	47.47	46	352
Columbia, S. C.	47.55	62	568
Selma, Ala.	50.75	60	724

From this table an estimate can be made of the occurrence and length of drouths that may be expected in these regions. From facts relating to conditions of rainfall, the effect of drouths on growing plants, and the quantity of water required to produce each pound of dry matter, it can readily be seen that either the conservation of the moisture in the soil or the direct application of water is essential in agricultural production if losses are not to be incurred from this source.

Dry farming. The conservation of moisture by cultivation, known as *dry farming*, is a method of treating the surface of the soil in such a manner that evaporation is reduced to a minimum. In humid regions this is carried on only to the extent of frequent shallow cultivations that cover the surface with a dust mulch which prevents cracking of the ground and keeps the water from being raised to the surface by capillarity and taken up by the dry, warm air. The same results may be secured if the soil is covered with some thin covering such as straw or other light material.

The dry-farming method, as practiced in semiarid regions, consists in cultivating the soil in such a manner that a large percentage of the rainfall is conserved in the soil until there is a sufficient quantity stored up to produce a crop. A crop is raised on an average of every other year. As soon as a crop is harvested the soil is plowed and packed by means of special tools, and a sufficiently loose covering is kept over the surface to absorb moisture and prevent evaporation. It is cultivated just enough to keep down vegetable growth and maintain proper soil conditions. Plants which use a minimum of water in their growth and fruitage are selected. Dry farming cannot increase the quantity of moisture in a region. It is only a method of conserving as much as possible of the water that naturally reaches the soil. The time that must elapse between crops must be such that sufficient water is furnished by the natural rainfall minus the small loss that will inevitably occur.

Fall irrigation. The storage of moisture in the soil is used in other ways than that of dry farming. After harvest a large quantity of water was formerly permitted to go to waste because there was no immediate need for it in crop irrigation. Water which is available at periods of the year when there is no plant growth is now frequently allowed to saturate tracts of land not included in the farming areas of the more valuable crops. The water thus stored in the soil is sufficient the following year to produce grass and crops that mature early or do not require a large quantity of water in their growth. This method of irrigation is known as *fall irrigation*.

Winter and spring irrigation. When the water is permitted to saturate the ground during the winter months under practically the same conditions as described for fall irrigation, it is known as *winter irrigation* and can be practiced only where the winters are mild and open. Early *spring irrigation* consists in saturating the soil with water that has been collected in reservoirs from the melting of snows or from winter rains. This water is applied before the growing period begins.

Crop irrigation. Dust mulch, dry farming, and generally fall, winter, and spring irrigation are methods for the conservation and use of water that under the ordinary conditions of farming would go to waste. *Irrigation* proper is the application of water to the growing crop at a time when the moisture is actually needed by the plant. There are three methods of true irrigation: surface, subsurface, and spray.

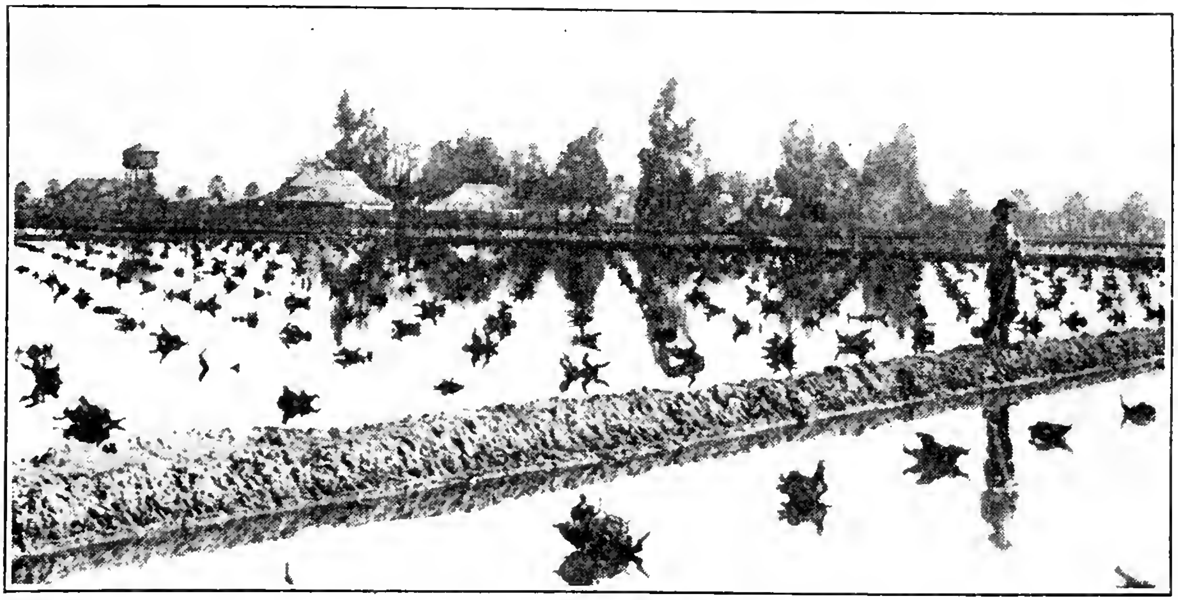

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FIG. 208. *Flood irrigation*

Surface irrigation. There are several methods of surface irrigation, as follows:

Wild or free flooding. Wild or free flooding (Fig. 208) is one of the pioneer forms of irrigation. It is applicable to grains, alfalfa, and grasses and consists in permitting a free flow of water over the entire surface of the ground. It is necessary to have a surface free from knolls or depressions, and there should be sufficient slope to the land to cause the water to move steadily in one direction. This method is the ordinary one for fall, spring, and winter irrigation and can be used on steep lands. The water supply is carried by ditches along the upper side of the field and is permitted to escape at sufficient intervals to cover the land with a sheet of water of uniform depth at short distances from the supply ditch.

Border method. The border method of flooding (Fig. 209) is employed in the irrigation of grasses and cereals. Ridges are thrown up with a plow down the line of the general slope, from 20 to 30 feet apart. The water is permitted to flow between these ridges, one after another. In this way the water is under control and does not spread to such an extent as in wild flooding. Where the supply ditch is small, it is more satisfactory than the former method of flooding.

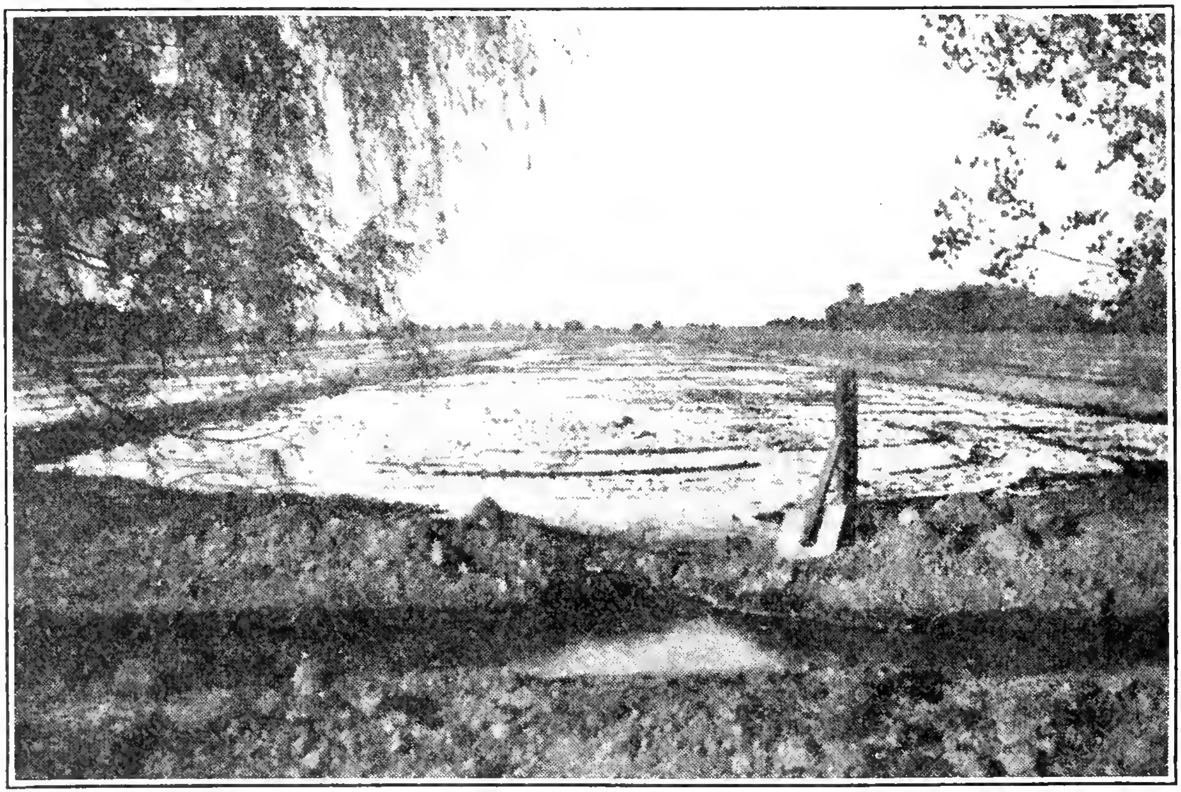

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FIG. 209. *Border irrigation. These borders have excessive length and width.*

Check method. The check method (Fig. 211) is also used for the irrigation of grass, cereals, sugar beets, and similar crops. In this method the field is divided into a system of checks or compartments, each check being comparatively level, with small ridges on all sides. The supply ditch flows down a ridge and is permitted to enter the check through an opening in the bank of the ditch or by means of a dam placed in the supply ditch, the side above the dam being cut out with a shovel. As soon as a check has received the proper quantity of water, the flow is stopped and the water is turned into the next check. When the checks are in the form of squares or rectangles, they are known as *rectangular* *checks.* Where the slope of the ground is such that the supply ditch is carried across the field in an irregular line following the contour, the checks are made to correspond

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FIG. 210. *Slip-joint pipe used for irrigating alfalfa*

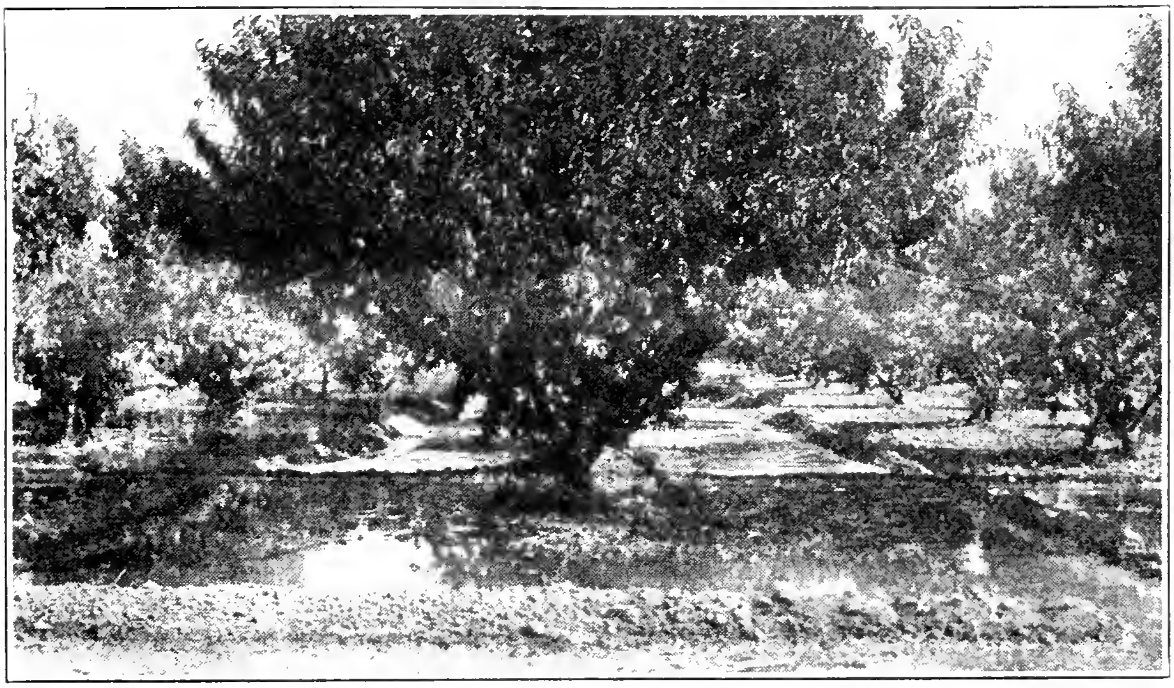

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FIG. 211. *Check method of irrigating peaches*

to the shape of the supply ditch and are known as *contour checks* (Figs. 212, 213).

Basin method. The basin method (Fig. 214) of irrigation is limited almost entirely to the cultivation of fruit trees.

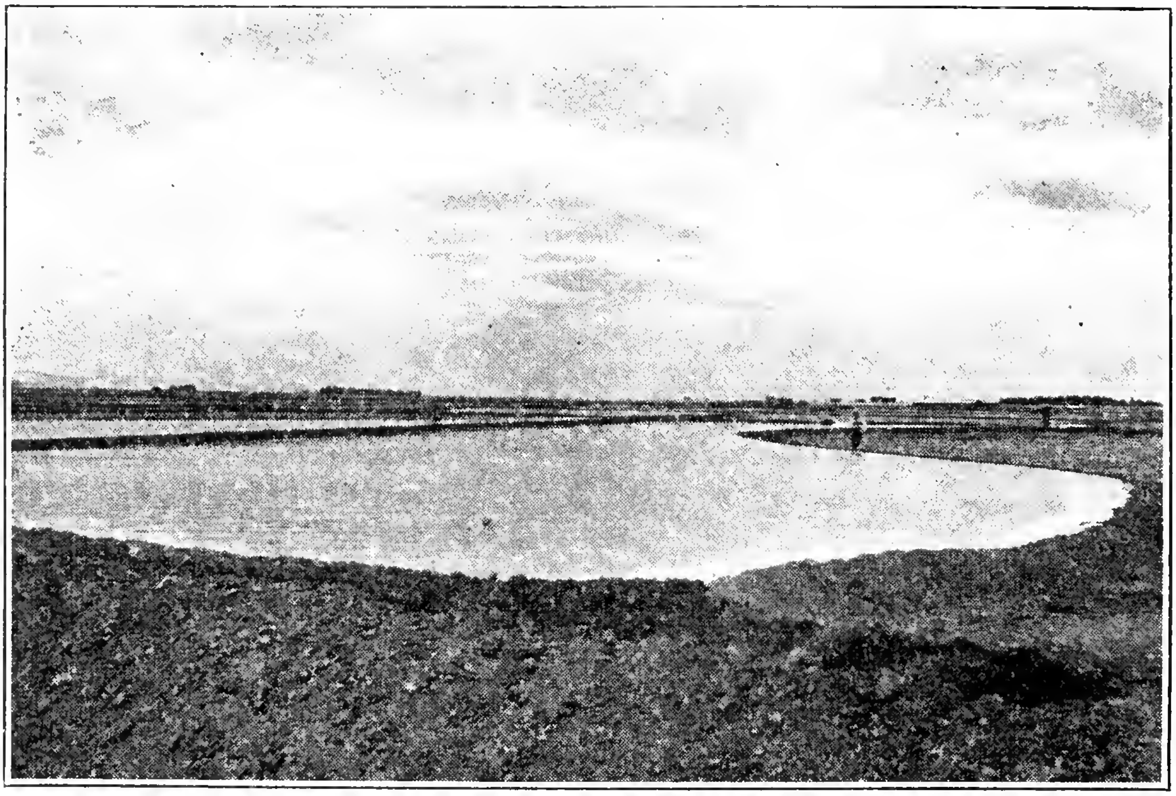

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FIG. 212. *First flooding by a contour border check*

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FIG. 213. *Contour terracing for irrigation*

A ridge is thrown up around each tree, thus forming a small basin. This basin is filled with water from a supply ditch which comes in on a ridge or by means of pipes.

Furrow method. The furrow method (Fig. 215) is used in irrigating crops planted in rows, such as garden truck, bushes, and small fruits. The water is carried in the supply ditch along the upper side of the field. Furrows are formed with a small plow or other tool and the water permitted to flow down to where it is absorbed by the ground between the furrows. These are placed sufficiently close together so that the proper quantity of moisture will be taken up by the soil. In crops such as potatoes and garden truck raised in rows close together a single furrow between each row is sufficient. In widely planted crops a furrow close to and along either side of each row may be necessary. This method does not saturate the surface of the soil, which is an advantage in growing some crops. A large quantity of water is not lost by evaporation, but in an open, porous soil much water may be lost by downward percolation, since

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FIG. 214. *Basin method of irrigating a prune orchard*

the furrow opens up the soil and carries the water to a depth below the surface. This method with a large furrow is extensively used in the irrigation of orchards, and with a small furrow in the irrigation of gardens and small fruits. Sufficient water is turned into the furrow to keep up a continuous current and to supply absorption, but not to such an extent that there will be a current strong enough to start erosion.

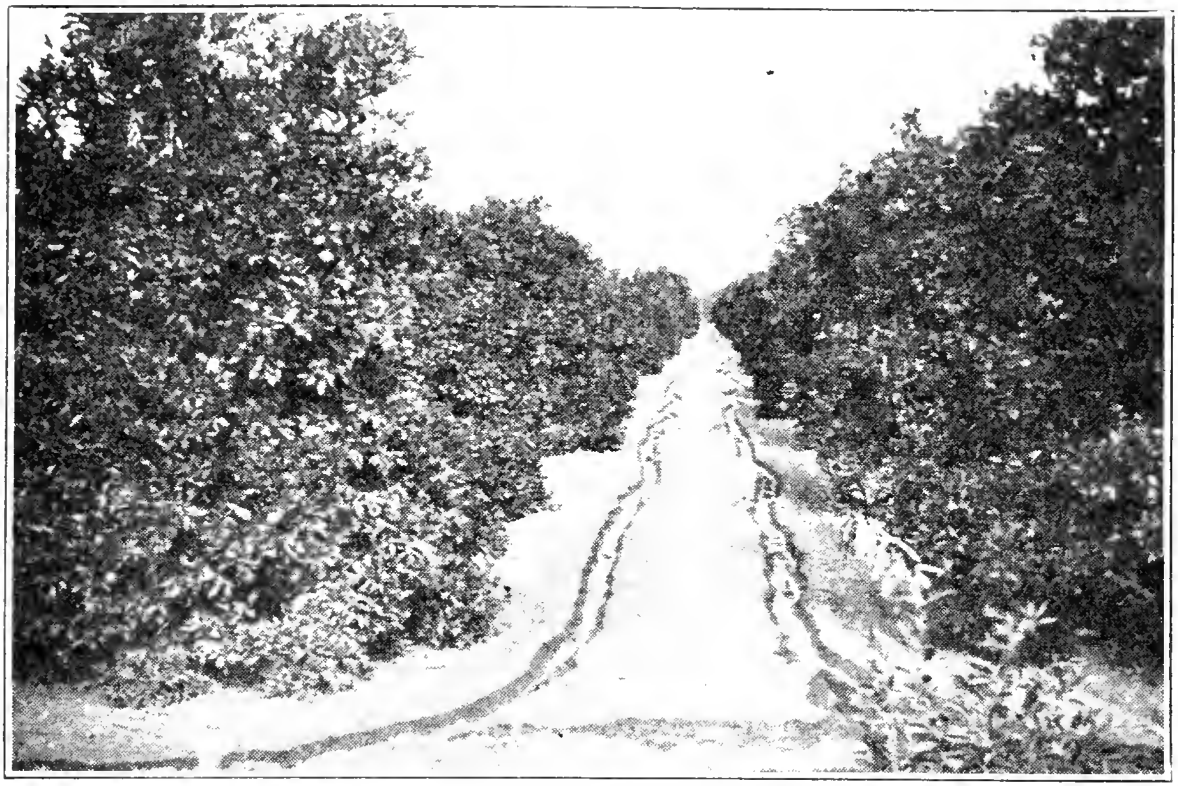

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FIG. 215. *Furrow irrigation in orange orchard*

Conveyors of water. While the open ditch is the common method of carrying water to the point of distribution in surface irrigation, it is not the only way. Conditions of the land sometimes make it impracticable to use open supply ditches, or the supply of water may not be great enough to stand the seepage and evaporation losses and other methods are employed. Canvas or other forms of hose are used, particularly in the basin and check systems. Rectangular wooden troughs or flumes (Fig. 216) have been employed by gardeners for carrying water to the head of the furrow, holes being bored in the sides to permit the water to escape and then closed with wooden plugs or pieces of tin when sufficient water has been admitted to any one furrow. It is also customary in some localities to lay underground pipes with standpipes coming to the surface at the distributing points. The standpipe may discharge directly into the furrow or check or the water may be carried a short distance through a hose. These methods of bringing in the water supply are more expensive in first cost, but they frequently save expense in the work of distributing water and, since they prevent waste, make it possible to irrigate a greater area with a given quantity of water.

Subsurface irrigation. Subsurface irrigation is a system in which pipes are laid underground at the places where the water is needed. The supply of water is turned into these pipes and escapes at the joints or through special openings, the water passing out laterally into the soil by absorption. This method is very satisfactory from the standpoint of cultivation and convenience in applying the water, but it is only under special conditions of soil that it distributes the water in a satisfactory manner. In an open soil the action of gravity tends to pull the water downward and there is great waste. In soils with an impervious stratum

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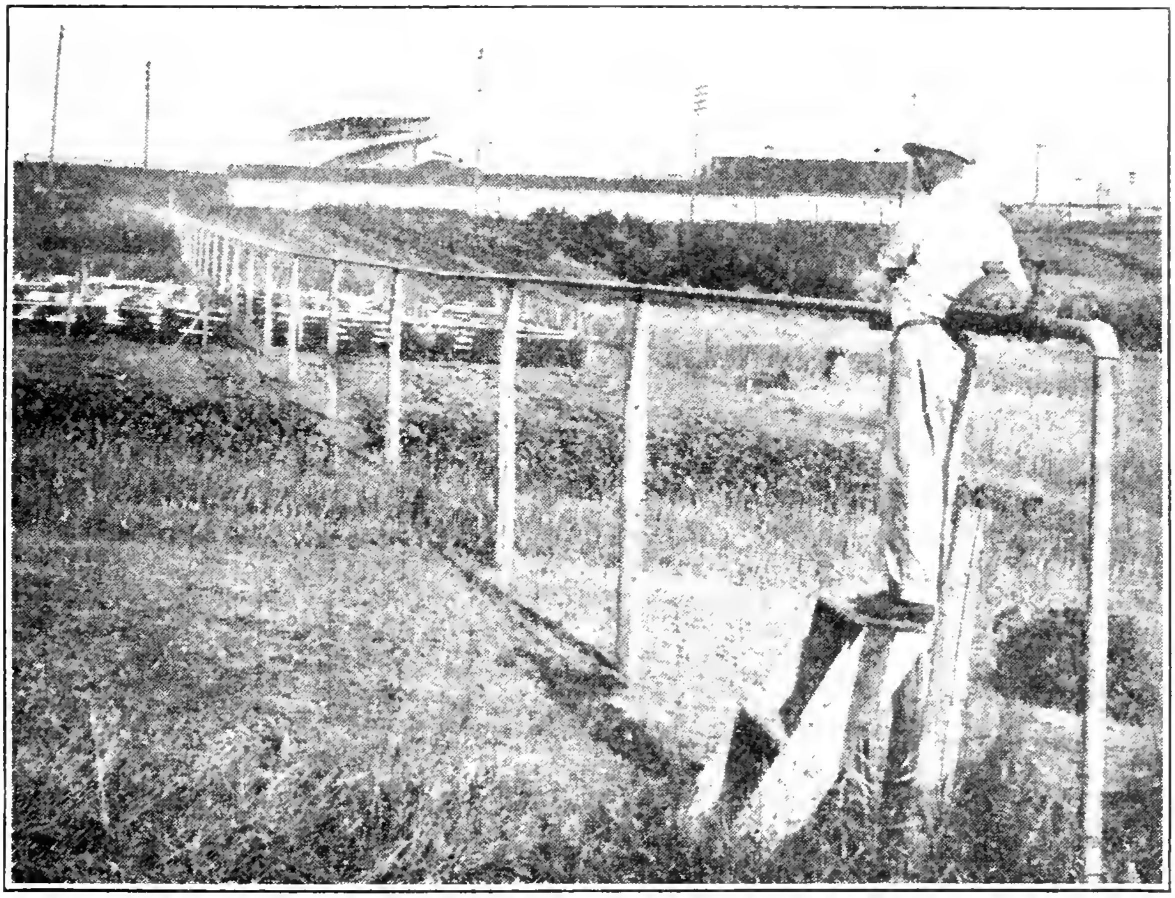
FIG. 216. *Irrigating strawberries by rectangular flume*

near the surface, which prevents the escape of the water downward, good results are secured. It is necessary that clean water be used, as sediment carried in the water will be deposited in the pipes when the water is taken up by the soil. In a few localities drain tile has been laid in such a way that during the wet season it serves for drainage purposes and during the dry season the outlet is cut off and the water supply is delivered through the tile, which then serves as a subsurface irrigation system. However, it is only occasionally that this combination will work to any advantage.

Spray irrigation. The spray method is a system which has been developed from the sprinkler in its use on lawns, and is the popular method for irrigation in the East, where it is much more extensively used than in the West. It is applicable to small areas and small water supply and does not require any special preparation of the surface. Furthermore, the application of the water requires very little attention. The first cost of the system is comparatively large, but in the estimation of gardeners and small fruit growers its merits from all other standpoints outweigh the initial cost.

Hose with movable nozzles fed from underground pipes or circular nozzles directly connected with the pipes are used. This system is applicable in greenhouses, cold frames, hot beds, or field irrigation. The method of overhead spray lines fed from an underground main is the one most favored at the present time (Fig. 217). The water is piped to the points of distribution in the field and distributed by means of pipes supported on posts, the pipes being of sufficient height to allow a team to pass under them. These pipes decrease in size from the supply pipe to the outer end, so that the quantity of water delivered and the pressure are constant throughout the pipe. To distribute the water properly and to throw a spray as great a distance as practicable, small brass nozzles are inserted approximately every

4 feet throughout the length of the pipe line. The line is so constructed that the rests on top of the posts are small rollers, and it is attached to the supply pipe by a turning union, so that the entire pipe may be revolved and in this manner the line of nozzles can be turned to the opposite side of the post. A line of pipe several hundred feet long can be readily turned, and a number of parallel lines can be connected in such a way that turning one will turn all of them. The time actually required for the irrigation under this system is reduced to a minimum, since the gardener can open the valve and start the water, turning the pipe as required in a very few minutes. It can be stopped at the end of the day's work by the closing of the supply valve, or, where desirable, the system can be left in operation during the night. The main requisite for this method of irrigation is sufficient pressure—25 to 45 pounds—on the nozzles to cause them to throw the spray the proper distance.

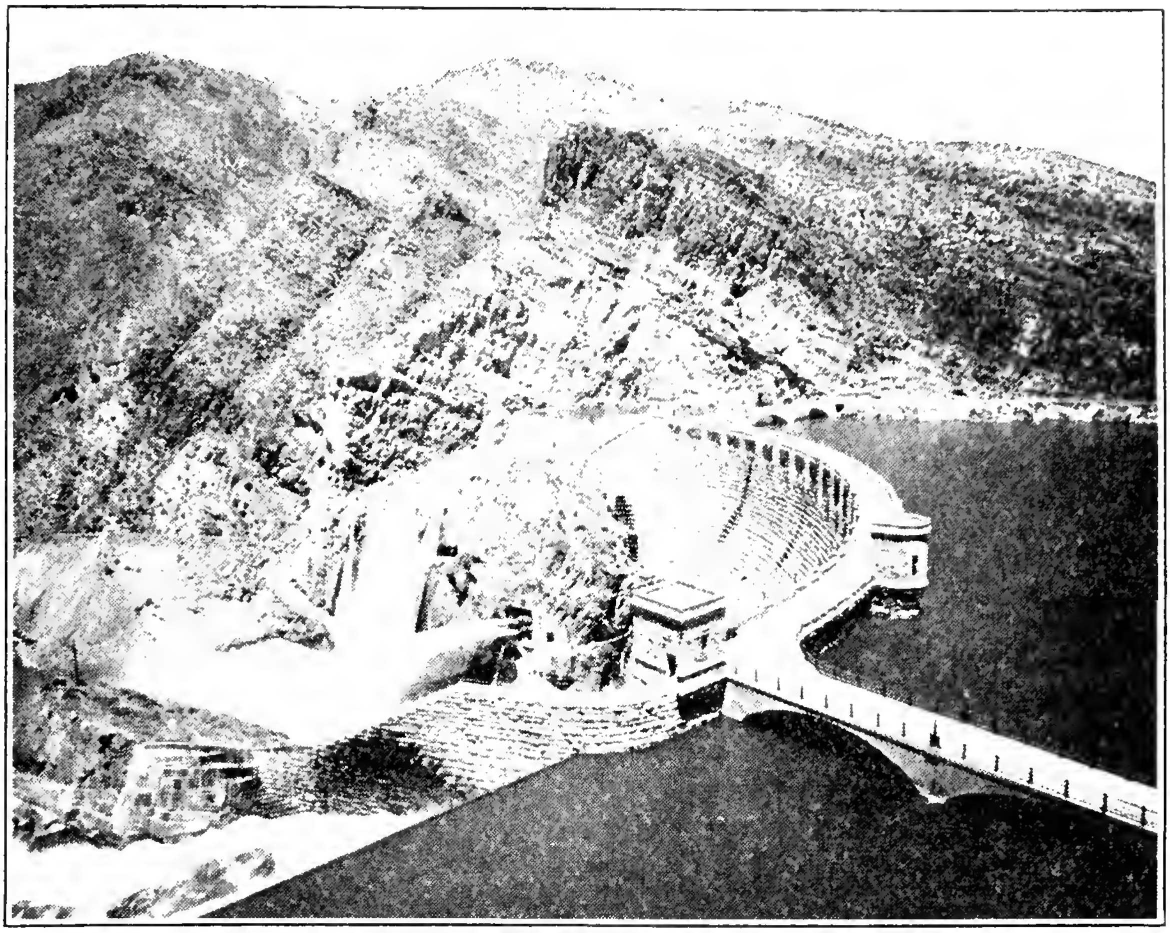


After University of Minnesota

FIG. 217. *Irrigating garden by overhead spray*

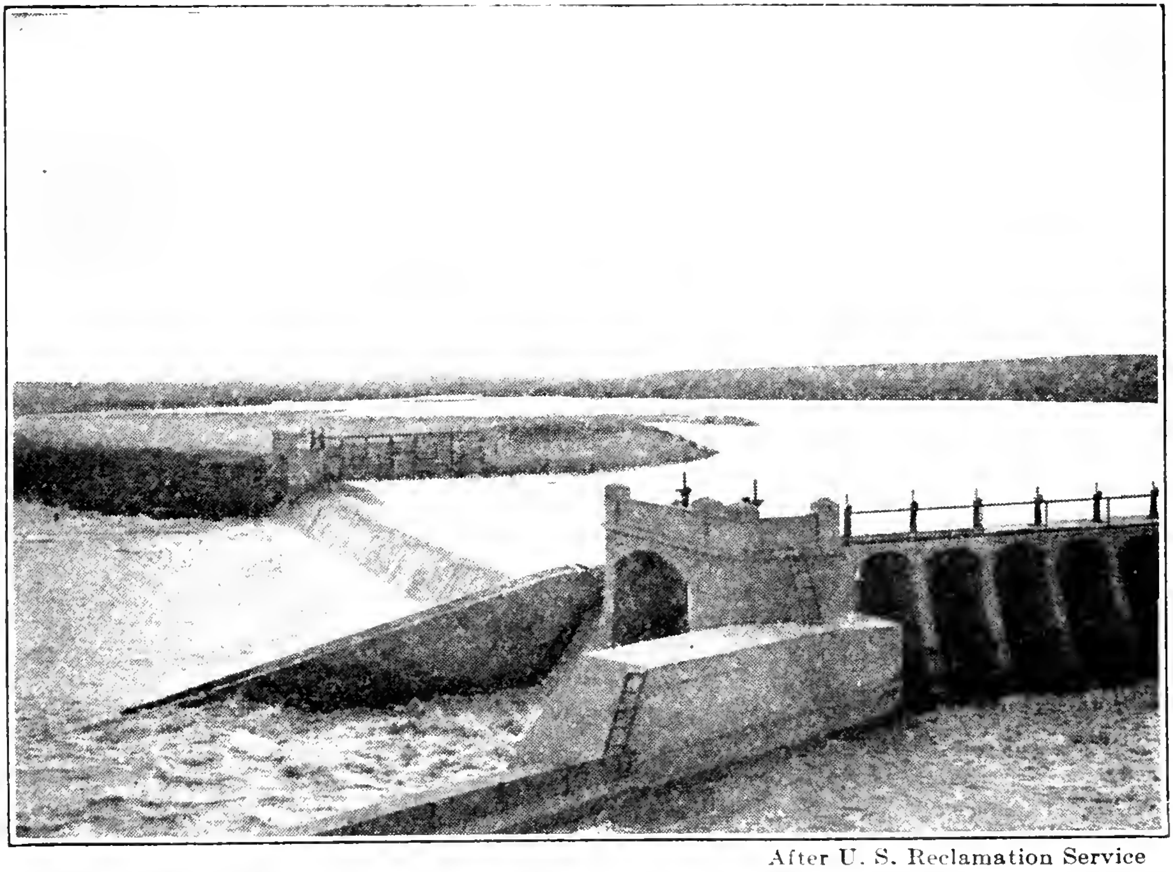
Duty. Duty of water is usually understood to mean the relation between a given quantity of water and the area of land which it serves. *Gross duty* is the quantity delivered at the reservoir or at the pumps and *net duty* is the quantity delivered by a supply ditch to the field. There is always considerable waste due to evaporation and seepage between the source of the water supply and the crop irrigated. The gross duty may be several times the net duty. For example, for each acre irrigated there might be liberated at the reservoir 5 acre-feet, which would be gross duty, but by the time the water was actually distributed there might be only sufficient to furnish 2½ acre-feet, one-half of the water being lost in transmission. Water is said to have a low duty when there is a large quantity leaving the supply point in comparison with that which reaches the crop. It has a high duty when the quantity reaching the crop is nearly the same as that which leaves the supply point.

Water supply. Sources of water for irrigation vary with the locality. For large systems in arid country dams (Figs. 218–221) are constructed and the water in flowing streams is impounded in large reservoirs. Where streams are not available, underground strata are tapped by wells and the water is pumped at the point where it is to be used. In plains country, where other sources are not available, dams are constructed across ravines and valleys and the water from the melting snows and winter rains is impounded and used for irrigating small tracts, or as winter and spring irrigation on areas of pasture lands. In humid regions water-bearing strata near the surface of the ground are developed by means of wells for spray irrigation. Lakes and small streams, when available, are used for the same purpose. Where the water supply is limited, as in a well, some economical method of placing the water on the land is essential. In arid country great expense is incurred for lining supply ditches to prevent waste of water in passage from the supply point to the distributing point.



After U. S. Reclamation Service

FIG. 218. *View of Roosevelt Dam and Spillway on the Salt River, Arizona*



After U. S. Reclamation Service

FIG. 219. *Whalen Diversion Dam on the North Platte River, Nebraska*

Over-irrigation. Where water is abundant there is a tendency to use an over-supply on the crops. Canal leakage and over-irrigation create a tendency for tracts of land otherwise arid to become swampy. The seepage from over-irrigation and from large supply ditches passes through pervious strata to the lower lands, causing them to become swampy. Continuous irrigation frequently causes lands to become impregnated with alkali. In order to relieve the land of surplus moisture or an accumulation of alkali, extensive drainage systems have been installed. Where the land is underdrained, the application of the water on the surface dissolves the alkali and carries it through the soil into the drains and washes it away. The drainage of irrigated lands is based upon different conditions from the drainage of lands saturated with rainfall for the reason that the water supply is coming entirely through the underground strata and is

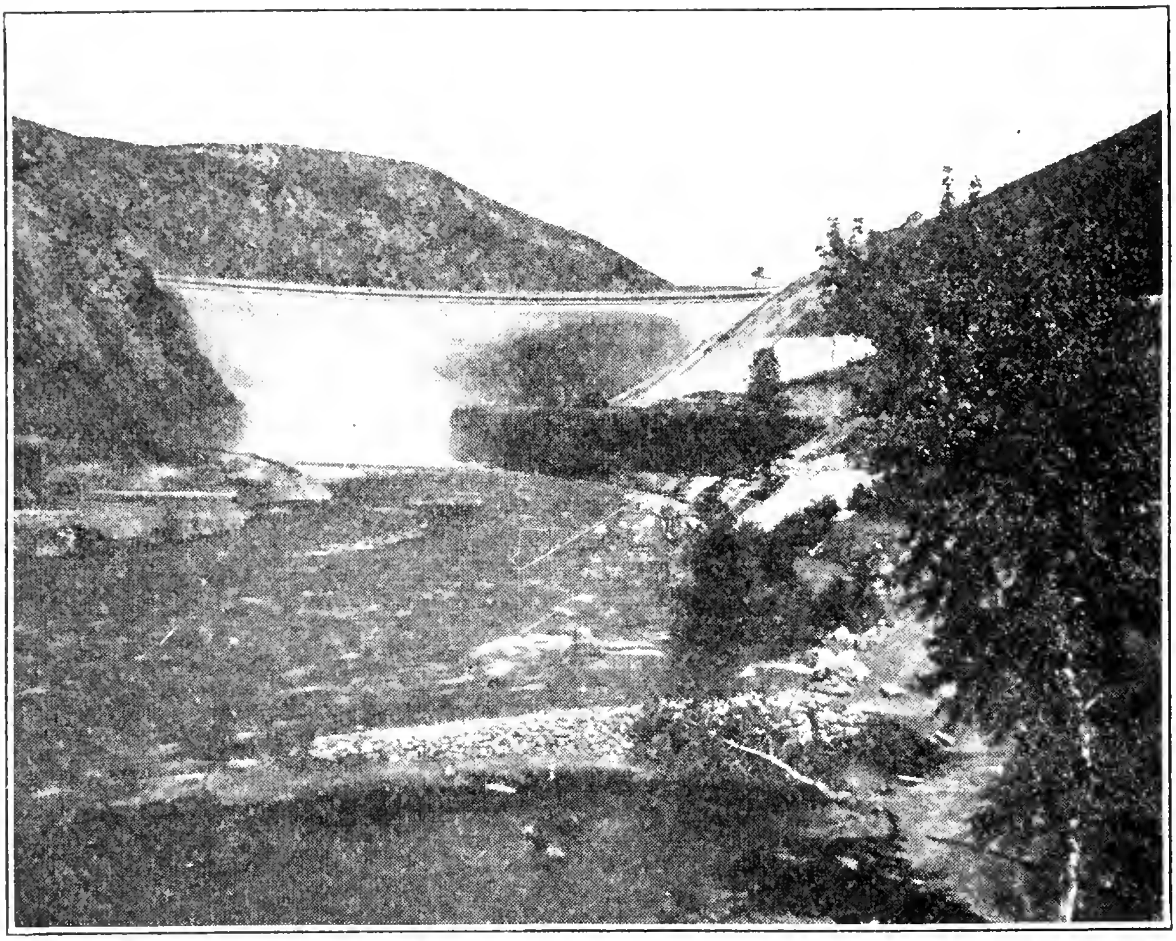


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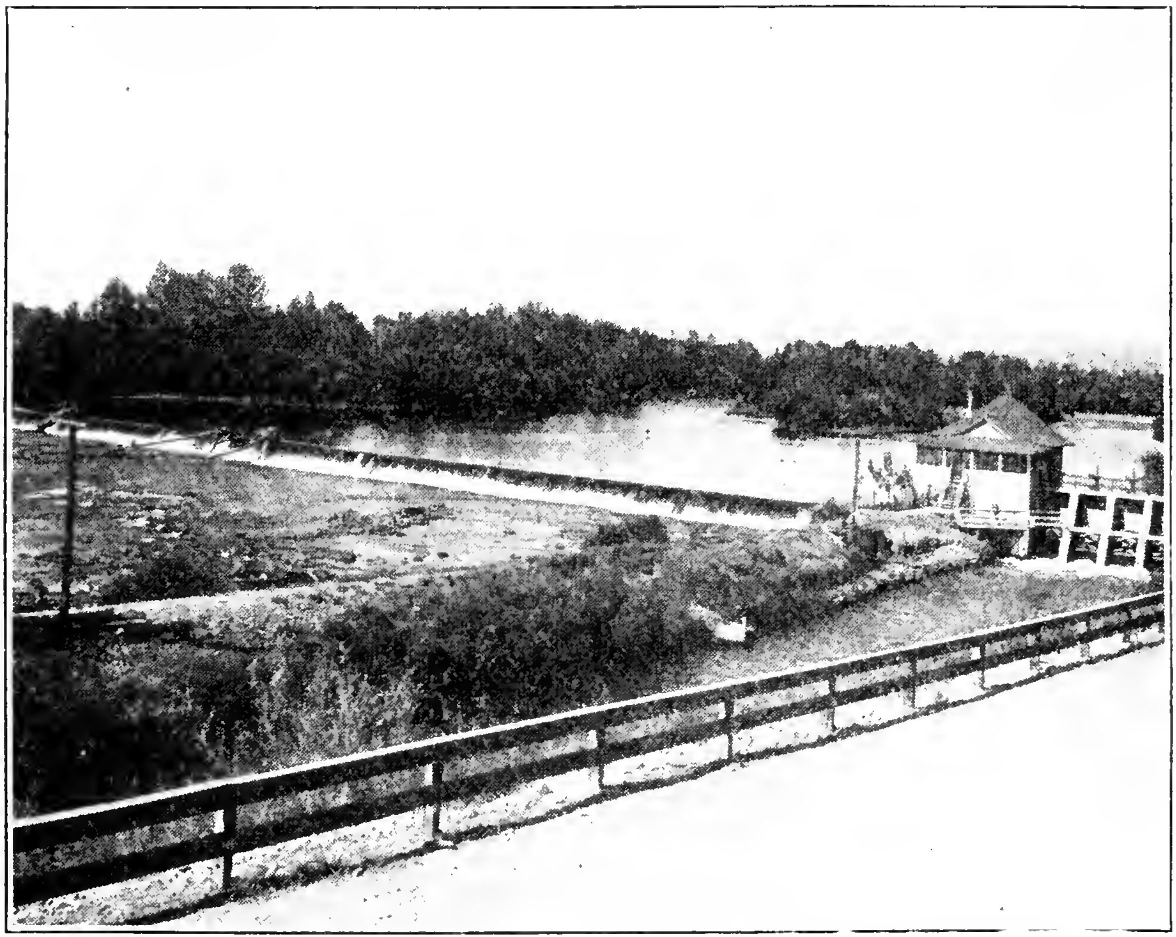
FIG. 220. *The Arrowrock Dam, near Boise, Idaho*

usually under pressure. It has been found advisable in constructing drains for irrigated lands to sink small wells into the water-bearing strata which will allow the water to rise and flow away through the drain.

Application of water. The conditions under which irrigation is practiced vary so much with soil, climate, and crops that it is out of the question to give any definite rules in regard to the time of application or quantity of water to apply. Many of these things must be learned by experience under conditions existing in any locality. The water should be applied to the plant before it actually begins to suffer.



After U. S. Reclamation Service

FIG. 221. *Diversion Dam on the Yakima Project, Washington*

In the humid states where the spray system is used ¼ inch is considered ample for seed beds and from ½ to 1 inch for a fruiting crop. Six acre-inches a season is considered the maximum. In arid regions where surface irrigation is used field crops require from 2 to 5 acre-feet. The best method of applying the water also varies with the nature of the crop, the soil, and climatic conditions. Irrigation Investigations, Bureau of Public Roads, United States Department of Agriculture, Washington, D. C., has prepared numerous bulletins relating to individual crops and the proper methods of irrigation, as well as to the various appliances and methods of applying the water. These publications may be had on request, and persons interested in any special crop or locality are advised to write to that office for information.

Comparison of methods. Any system of irrigation that is permanent and will do thorough work is expensive. When the subirrigation or the spray system is used, expensive equipment is necessary. When the surface methods are used, much time and labor are required to place the surface of the land in suitable condition. In pioneer days, when land was plentiful, no attempt was made to irrigate any but tracts of land that were naturally favorably situated. Rough and uneven lands were neglected. The demand for increased farm lands and the scarcity of water due to more water users have made it necessary to improve unfavorable lands and to place them in such condition that the water available will extend over a maximum area. The arrangement of the farm and the laying out of fields should be done after the location of the water-supply ditches has been determined. The system of farm management and cultivation must adjust itself to the water supply to prevent evaporation and to secure the greatest benefit to the plants. After irrigation the land should be cultivated as soon as the water is turned off, unless the subirrigation method is used. The method of applying the water should be one that will adapt itself to local conditions and will distribute the water uniformly throughout the soil layers so that it will reach the area occupied by the plant roots and be available to the plant. Economy of both labor and water should be considered, as in the majority of irrigation systems a waste of water means an unnecessary outlay.

Benefits of irrigation. Besides the increase in quantity and quality of the crop produced on irrigated lands, there are numerous other benefits which may attend the use of a system. Irrigation has been employed extensively for frost protection. Growing crops that are sensitive to a late or early frost can be saved if the water is turned on during the night when there is danger of the temperature dropping to the freezing point. Delicate crops have been saved by the use of water when the temperature fell as low as 27° Fahrenheit for a short period. Cranberry bogs are irrigated by the flooding system for the purpose of retarding early spring blooming, protecting them from frost during the ripening period, and water is permitted to freeze on the bogs during the winter to prevent the vines from being heaved out of the soil by repeated freezing and thawing. Rice fields are flooded to prevent birds from eating the rice seed and to kill weeds. Water, when properly applied, will hasten the ripening period of fruit several days, and the season for propagating by budding can be prolonged, because the water will cause the bark to slip for a longer period. In some localities the sediment carried by the water serves as fertilizer. The fertility of the Nile Valley is attributed to the silt annually deposited by overflowing water. Crops which are transplanted in the fields are greatly benefited by irrigation, since the moisture supply can be controlled to promote rapid growth, maximum yield, and high quality of product.

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CHAPTER XIV

DRAINAGE

GENERAL CONSIDERATIONS

The presence of superfluous water is as detrimental to agricultural land as an inadequate supply, but it generally does not require so great an expenditure of labor and money to remedy the former condition. The method of disposing of the water will depend to some extent upon its source. Early drainage systems are of historic interest only, and this chapter will deal with present-day practices.

Benefits of drainage. Drainage increases the productivity of wet lands and reduces the labor necessary for cultivation. It permits of freer circulation of air into the soil, which results in the deeper penetration of frost in winter and earlier warming of the ground in the spring, both of which are of benefit to agriculture. Roots extend deeper into a dry soil, and for this reason drouths are not so disastrous. Soils that contain no free water are not affected by winter heaving or summer cracking, and as a result plant roots are not torn apart in the winter nor injured by the dry hot air which enters cracks in the earth in a dry season. Erosion of the fertile surface soil is prevented, and the light vegetable matter and fertilizing materials on the surface of the crop-producing fields are left distributed where needed and not floated away at every rain.

All health authorities recognize that sanitary conditions are improved by the removal of surplus water, and no other measure is so effective in destroying the breeding places of mosquitoes, greenhead flies, and other annoying insects that require wet ground and small ponds for their reproduction. All road experts agree that thorough drainage practically solves one-half of the highway problems of the average community.

Objections raised by landowners. The need of drainage is usually readily admitted by intelligent farmers, but the cost of the work and the location of a ditch upon their land frequently arouses opposition.

The amount that can properly be spent on drainage work depends upon the crops raised and their value. Lands suitable for orchards and gardens justify an expenditure of large amounts per acre for improvements as compared with the amount that might be profitably spent on lands suited only to hay and field crops. The availability of markets and the demand for certain products determine to a large extent the advisability of constructing expensive drainage systems.

It is not an uncommon thing for a landowner to fight a drainage assessment on land which has a market value of from $20 to $30 per acre, and almost at the same time buy another tract of similar land at the market price, the idea being that the acquisition of more land denotes greater prosperity. He does not realize that one acre of thoroughly drained land might bring him a greater income, with one-half the labor and expense of cultivation, than two acres of undrained land, and that it could have been acquired at one-third to one-half the cost of the other acre. Other landowners oppose drainage improvements for the reason that the ditch will be located on their land, even in the face of the fact that from one-fourth to three-fourths of their land produces only about one-half of what it should in the ordinary year, on account of excessive moisture. Yet they prefer to stand this loss rather than to have one-fiftieth to one-eightieth of this land occupied by a ditch which would drain the entire tract so thoroughly that it could be cultivated up to the banks of the ditch.

Scientific planning and management. Once a landowner or group of landowners has been convinced that a drainage system is desirable and possible from a financial standpoint,

After University of Minnesota

FIG. 222. *Wet land in August, 1908, before underdrainage*

After University of Minnesota

FIG. 223. *The same land shown in Fig. 222, in August, 1912, after underdrainage*

the work should be planned and carried out in a thorough and scientific manner. A complete analysis of all the conditions affecting the working of the system should be made. The source of the water which saturates the soil needs attention This may be due to rainfall only, as in flat lands which are protected by intercepting ditches or levees. There may be an overflow coming in a very thin sheet from surrounding lands with a slightly greater elevation. Such an overflow is often so evenly distributed over the entire surface that it is overlooked and drainage capacity for a given area is provided when in reality there is moisture to be removed from several times that area. Seeps and springs may occur, caused by the water being carried by a porous stratum from higher levels. Such water may be distributed on the surface at a low velocity over a wide area and, instead of producing a running stream, keep the surface saturated for a long period. Drainage channels, unless conducted back into the dry land a sufficient distance to cut off the water-bearing stratum, will not give the desired results. The distribution of rainfall and conditions favoring evaporation, absorption, and percolation are all factors which have a bearing upon the drainage problem. These last are discussed in the chapter on climatology.

Elevation. To determine the rate at which the lands can be relieved of water it is necessary to know the fall per unit of distance, and to estimate cost it is necessary to know the depth of cut through the ridges or high lands. Therefore a determination of the elevation of the lowest point to be drained, with reference to the outlet, and the highest points through which the proposed channel will pass, with reference to the lowest points, is essential. The general surface conditions will determine the number of these elevations necessary. A flat surface sloping in one direction requires few elevations for a drainage plan, while a rolling country with deep depressions and intervening ridges will require a great many elevations for determining the depth of channel necessary to drain all of them and for finding the most practical outlet through the ridges.

Outlet channel. The outlet channel should be examined for the purpose of determining the height to which the water will rise in a flood period, the season of the year in which the flood occurs, and the length of time the outlet remains at flood height. A stream that floods when the frost is going out of the ground in the spring or once every eight or ten years might afford a satisfactory outlet for a drainage system, but if it floods between May and August two or three times a season, and remains at high-water stage for two or three days at each flood, it would be inefficient and crops would be drowned and the drainage system be rendered almost worthless.

Crops. Crops to be raised have an influence upon drainage plans, since some crops are much deeper-rooted than others and require drainage to a greater depth. To a certain extent the growing season determines the drainage required. Flood periods that might not injure one crop would completely ruin another.

Soil. The nature of the soil must also be taken into consideration. This will become evident in the work of excavating, as it takes much less labor and time to dig a satisfactory ditch or tile trench in one kind of soil than in another.

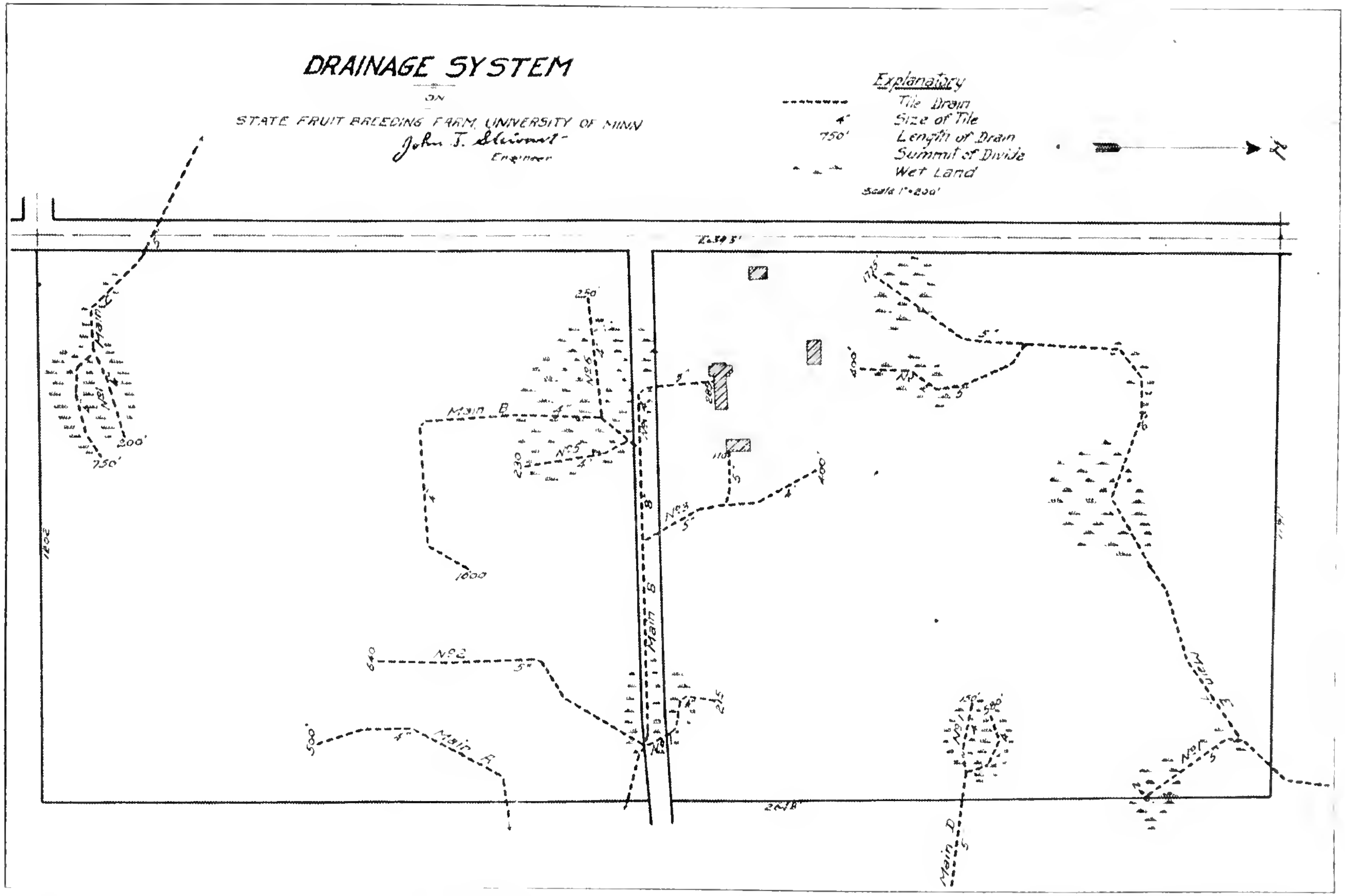
Cost. The cost of material and labor affect a drainage plan only in the first cost, but this estimate of the cost of the work may determine its construction. A proper consideration of this point will prevent delay in the work because the estimate is too high or future dissatisfaction because the estimate has been too low.

Run-off. Run-off is the water which is carried from the land either by the natural channels or by the construction of new channels. The quantity of run-off is dependent upon the slope, the condition of the soil, and the vegetable growth. A hard, firm surface prevents the rainfall from entering the soil and causes it to accumulate. As the slope increases, the velocity of the water down the slope is increased, there being a tendency for the water to collect in depressions. A hard, sloping soil will run off a large percentage of water and concentrate it upon lands having less slope. The flow of water from the surface is materially retarded by the vegetable growth.

Maps and surveys. The basis for all drainage improvement is an accurate map of the area to be drained. Such a map, known as a *topographic map*, is made by an engineer after a careful survey, and shows all local improvements, the boundaries of lands to be benefited by the drainage, and the boundary of the watershed. It should also show the elevation above a fixed point of all sloughs, lowlands, and the tops of ridges through which it may be necessary to construct the outlet channel. On this map the best location for the proposed drains can be laid out, and their grade, size, and approximate cost determined, after which the ditch or trench may be staked out, with such minor changes as are found necessary by conditions on the ground.

Contractors. In drainage construction it is important that the work be intrusted to persons who are properly equipped and experienced in this class of work. Ditch construction and tiling is a business in itself, the same as carpentry and masonry work, and, if it is to be carried on as efficiently as those classes of work, contracts must be let in the same manner. The bidder's record for past work should be taken into consideration as well as his bid. A low initial cost may be made very expensive by poor judgment or careless work done by the contractor.

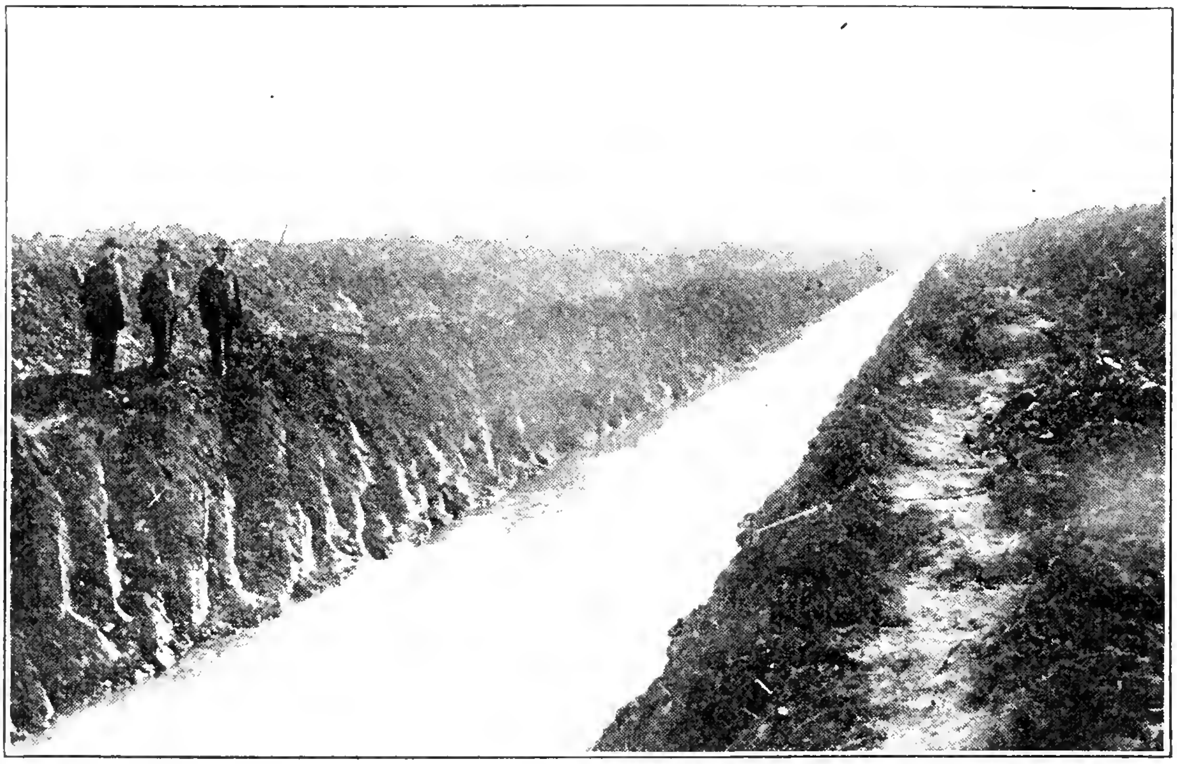
Method of drainage. One of the first things to be determined is the method of drainage to be used. Generally the choice will be between open-ditch and tile, or a combination of the two. The character of the ground, surface slopes, crops raised, and value of land all have a bearing upon the subject. However, in any locality an



After University of Minnesota

FIG. 224. *Tile drainage system for rolling lands. Dotted lines indicate tile lines; shaded lines, the summits of divides; figures, the size of tile and length of drain; dotted areas, wet lands.*

outlet or main channel by which the water may be carried away must be given early consideration. In some places nature has provided such outlets; in others it is necessary for several landowners to band together and construct a channel of sufficient size and depth to serve as the main outlet of a network of ditches which will give relief during wet years. On the individual farm it is necessary to have a thorough system of collecting the water as it falls and of carrying it to the main outlet.



After University of Minnesota

FIG. 225. *Outlet channel constructed by steam dredge*

Outlet. Drainage organizations often assess costs and give out statistics showing the cost per acre of drainage systems, giving the impression that complete drainage has been installed. In many instances the work actually done has been to furnish outlets only, and often those are inadequate, owing to the fact that tracts of lands are separated from the outlet channels by lands belonging to other owners. Such drainage systems do not furnish the proper relief for farm drainage. The drainage district, properly organized, should furnish, to each tract of land in separate ownership which has been assessed, the outlets which are necessary for the economical drainage of that tract, without having to cross the land of other owners. Outlet systems should be so planned that the necessary outlets are furnished, and at the same time due attention should be given to the lower part of the outlet or the natural stream into which it flows, to prevent the flooding of lands lying lower down. The drainage of one area at the cost of another is not good engineering, good agriculture, or good economy. The planning of outlets should be done with due consideration for all interests, to serve the land benefited in such a way that outlet privileges from land assessed cannot be withheld by obstinate owners of intervening farms.

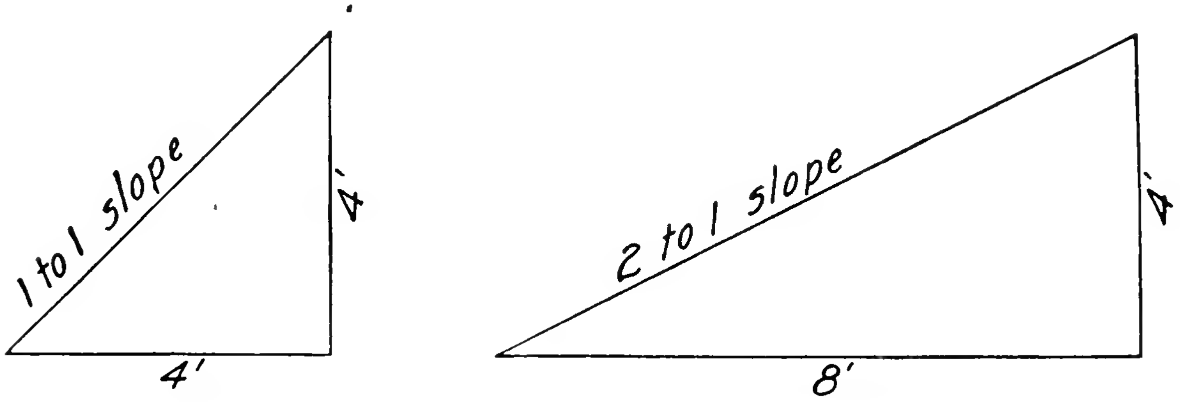
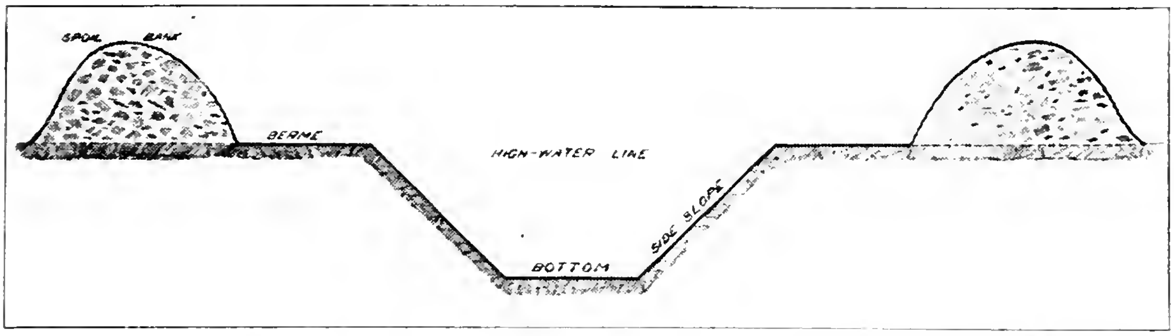


FIG. 226. *Diagrams of 1 to 1 and 2 to 1 slope*



After University of Minnesota

FIG. 227. *Typical cross section of a drainage channel constructed by a steam dredge. Indicated by technical names.*

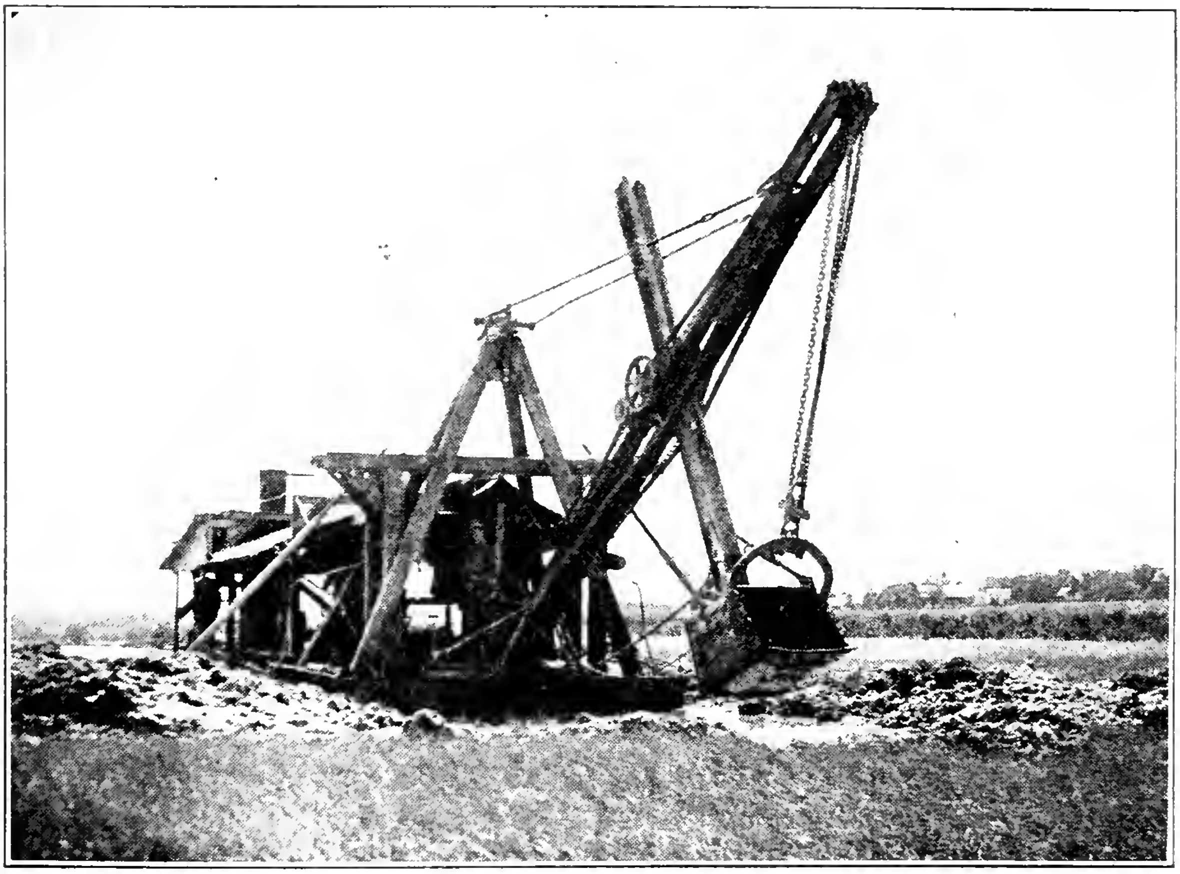
A drainage system, open or tile, works by gravity, and to remove the water there must be a fall. It has been common practice to run a drainage ditch into a slough at practically the same depth as the bottom of the slough. Such drainage does not give satisfaction, as the ground water is not lowered and the bed of the slough continues to be swampy. For good drainage the water channel must be deep enough in the lowest land, and of sufficient cross section, so that the water will be contained within the channel and not overflow.

After University of Minnesota

FIG. 228. *Construction of an open ditch 10 feet deep by means of slip scrapers*

Open ditches. Open ditches are essential for outlet channels, and where it is necessary to reduce the first cost they are used for collecting ditches. The area of land that can be drained by any other than open channels is limited, and their use is necessary for large watersheds. Ditch construction is estimated and priced by the cubic yard. The cost per yard, whether constructed by hand, with teams and scraper (Fig. 228), or by means of a steam dredge (Fig. 229), varies with local conditions and the size of the ditch. The price per cubic yard increases with width and depth in hand and team work; in dredge construction it decreases, and the excavation is not delayed by the presence of water or sticky material.

A 6-foot bottom is the minimum for a small-sized dredge, and ditches with a bottom width of from 50 to 100 feet have been constructed. The depth varies from 6 to 20 feet, the excessive depth being usually in a cut-off through a ridge. In the construction of outlet ditches it is essential to have the channel of a depth to furnish a good outlet for all lateral drainage; in flat country 6 feet is the minimum, and under many conditions of topography it should be 8 feet. Much of the lateral drainage will consist of large-diameter tile, and at the time of designing the main channel the fall of the lateral ditches and their depth at the lowest point must be taken into consideration, and the depth of channel determined which will give the required drainage from the lowlands along either side and some



After University of Minnesota

FIG. 229. *Small floating dredge*

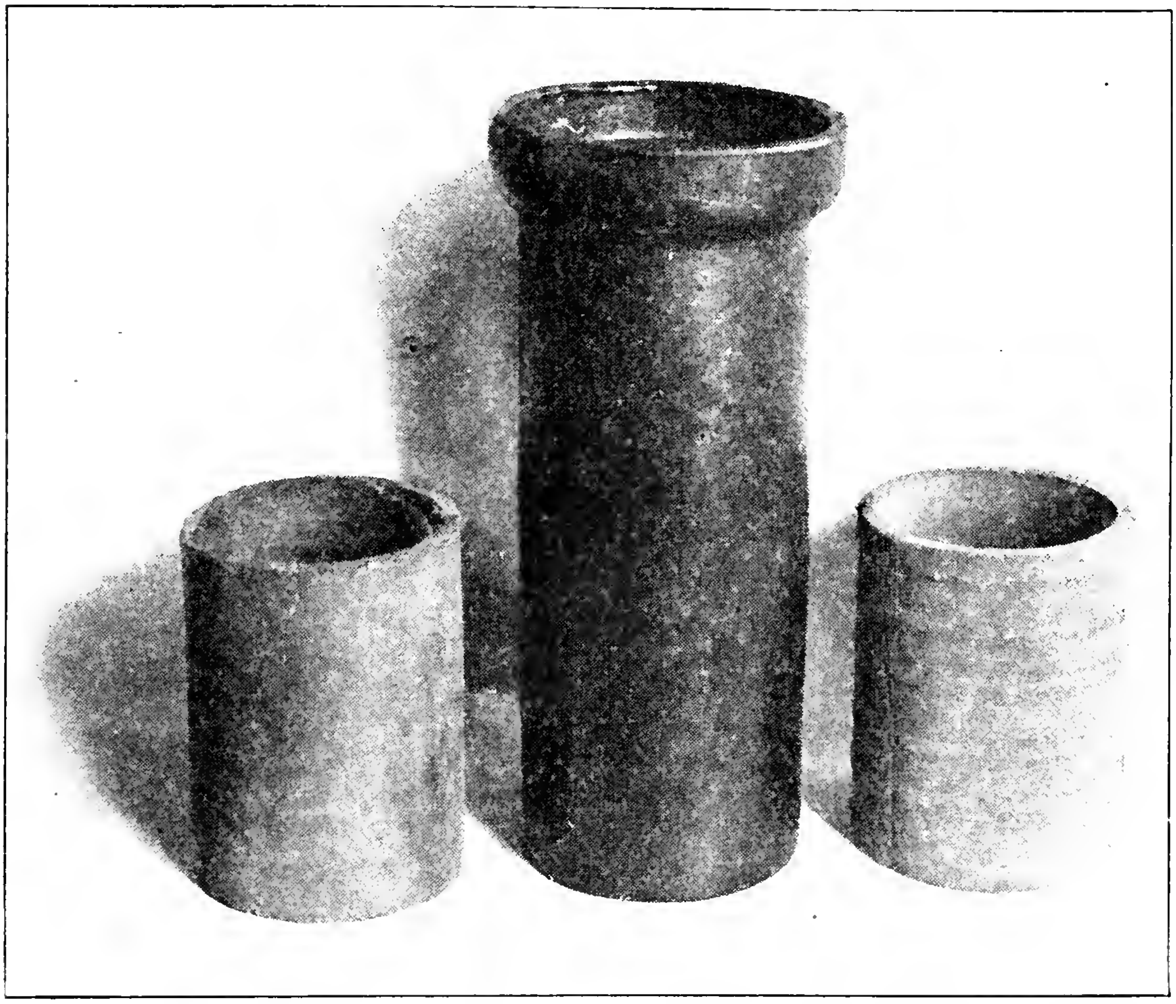
distance from the main channel. Many of these laterals may in turn be only outlets for collecting systems, and consequently the needs of each inlet must be carefully considered at the time of determining the depth of the main outlet channel.

Shallow open ditches. The cheapest and simplest collecting system is the shallow surface drain, which follows the low depressions or the shortest line between sloughs. This system of drainage can usually be worked out by the farmer. After a heavy rain, or in the spring, when the water is standing on the surface, the location of surface drains can be easily determined, and, by the use of a few stakes, can be permanently marked so that they may be retraced at any time. The surface water will give a fair idea of the depth of cuts needed through low ridges. These ditches can be made with a plow and slip-scraper, or push-grader, at any time during the working season when teams are not otherwise busy. They should be made wide enough to be readily crossed with farm machinery, so that they will not interfere with cultivation. If their beds are too wet for farm crops, they can be sown in grass and mown each year, which will keep them clear and often give some return on the land occupied. In the construction of surface drains care should be taken not to excavate deeper in the low places than through the ridges, as the object is to prevent standing water. By careful plowing, dead furrows can be made to act as laterals. Each rain will show up the points that are too high and give an idea in regard to the efficiency of the entire system, and the faulty places can be improved at the next working period. By intelligent and careful study and work on the part of the farmer, he can in the course of a few years, at a very small expense, place his land in such condition that the surface water will soon disappear except in some of the deeper and larger sloughs, where it can do no additional harm, and when these sloughs are drained his land will be practically free from surface water.

TILE DRAINAGE

Underdrainage. Because of the objections made to open ditches, methods of eliminating them have been developing for many years. The most satisfactory way is by the use of circular drain tile laid in a trench and then covered so that there is no waste land and no inconvenience in cultivation. If it is properly constructed, there is no maintenance cost.

At the present time there is no means of determining the drainage properties of a soil except by actual experiment and comparison with soils in a region which has been underdrained. The depth and width of tile drains depend on the rapidity with which water will pass through the soil and on the crops to be raised. In light, open soil, drains can be laid deep and wide apart. In heavy soil they should



After University of Minnesota

FIG. 230. *Clay tile, sewer pipe, concrete tile*

be shallow and close together, so that the water can readily reach them. Some crops require a much higher degree of drainage than others. In some close, tenacious soils, to get good drainage for orchard or garden purposes, it has been found necessary to lay the drains as close as 33 feet. In light, open soils used for field crops drains 300 feet apart have proved entirely satisfactory. The size of tile is dependent on surface conditions, grade per 100 feet, area drained, and the outlet. The following table shows the number of acres drained by tile of a given size and laid to a given grade:

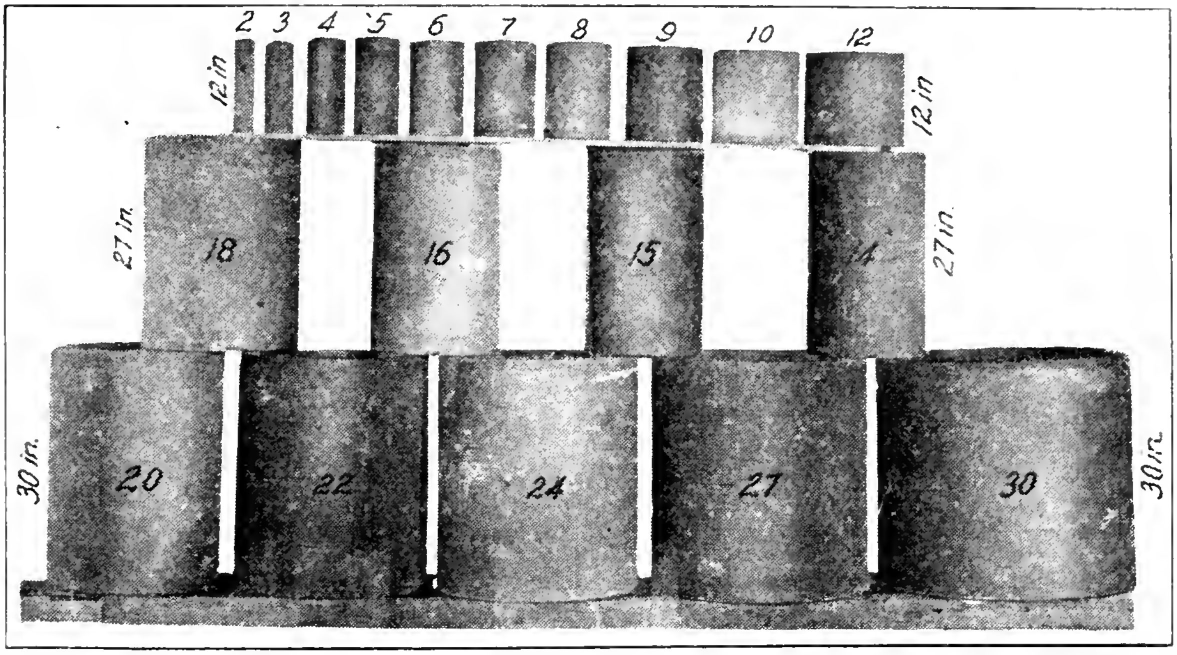
Table Showing the Number of Acres Drained by Tile of a Given Size and Laid to a Given Grade*

(This table is based on the removal of ¼ inch of rainfall from the entire watershed in twenty-four hours. Local conditions of soil and run-off will have some effect on the size of tile for the area drained, but the area given is as near as can be determined in a general statement.)

Grade per 100 Feet	.04	.06	.08	.10	.12	.14	.16	.18	.20	.25	.30	.40	.50	.60	.70	.80
Size of Tile	Number of Acres Drained															
4	3	4	4	5	5	6	6	6	7	8	8	9	11	12	13	14
5	6	7	8	9	10	10	11	12	13	14	15	18	20	21	23	25
6	9	12	13	15	16	18	19	20	21	23	26	30	33	36	39	42
7	14	18	20	23	25	27	29	31	32	36	40	46	51	56	61	65
8	21	26	30	33	37	40	42	45	47	53	58	67	75	82	89	94
9	29	36	41	46	51	55	58	62	65	73	80	92	103	113	122	130
10	39	48	55	62	67	73	78	83	87	97	107	124	138	151	164	174
12	64	78	91	101	110	120	128	136	143	162	177	205	229	250	271	290
14	100	123	142	158	173	187	200	212	223	250	273	316	352	388	419	444
15	120	147	170	190	208	224	240	255	268	300	327	378	424	465	501	536
16	142	174	201	224	246	266	284	301	317	357	390	452	504	553	597	639
18	198	243	280	313	343	371	396	420	443	492	540	625	700	767	826	885
20	264	324	374	420	456	494	528	560	590	660	725	834	935	1,020	1,100	1,180

*After Stewart, University of Minnesota.

Qualities of tile. Two classes of tile are in common use: clay and concrete (Fig. 230). Tile should be straight in length, circular in cross section, and well made. The test for good tile requires that it give a sharp metallic sound when struck with a piece of metal. Average tile overrun in length ¼ to ½ inch. Tile may not be square on the ends or perfectly straight, but when bowing in the tile or irregular ends do not occur in the same piece laying is seldom interfered with. Tile are sold by the thousand, supposed to lay 1,000 feet of drain, the overrun in length balancing the breakage and poor tile rejected at the trench.



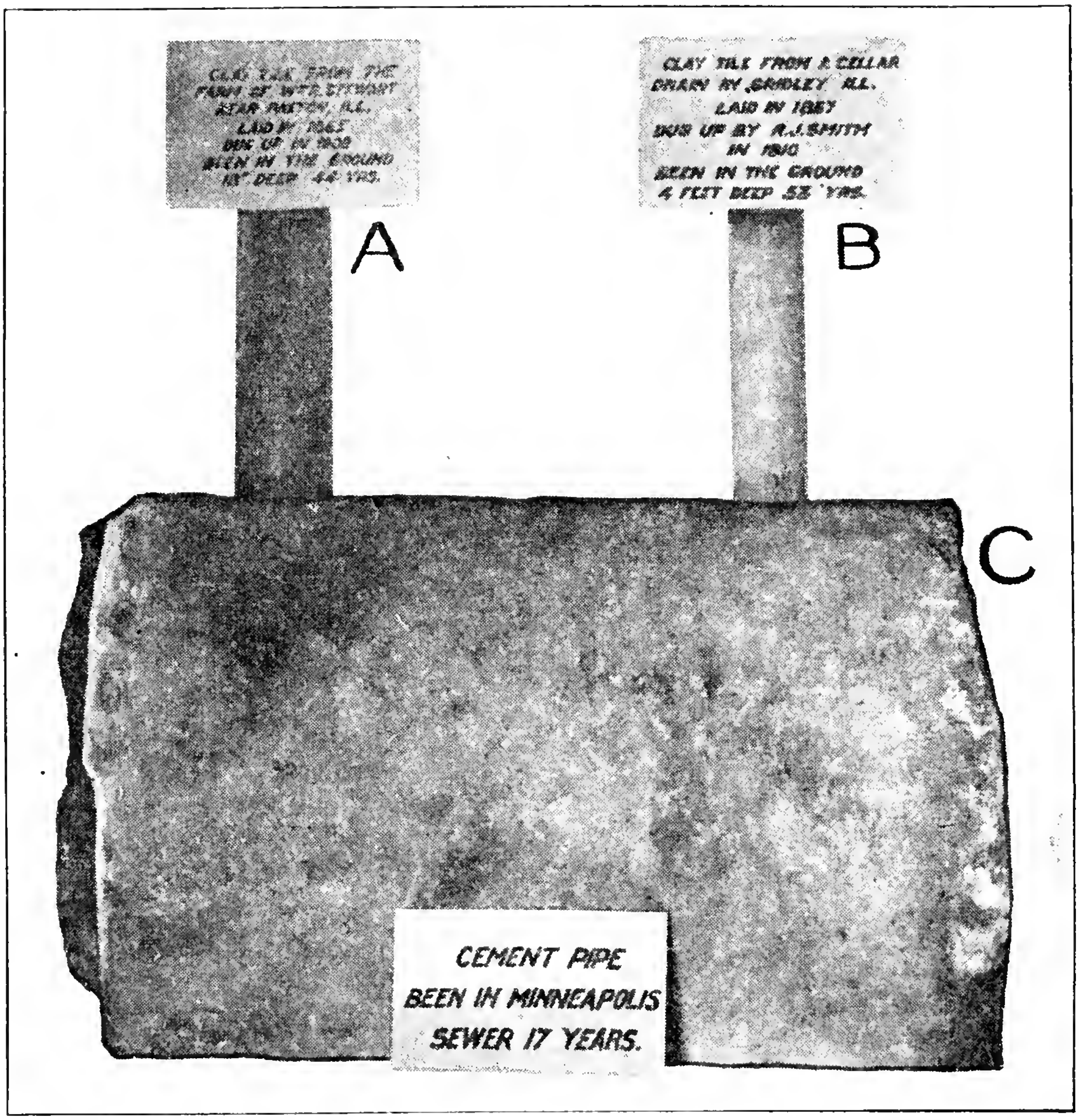
After University of Minnesota

FIG. 231. *Several sizes of tile*

Where they are subject to long shipments and hauls, they will not always hold out, but a good quality of pipe carefully handled will ordinarily lay the required number of feet.

Water enters the tile through the joints and not through the walls. Tile, unless very hard, will absorb a certain percentage of water, but this does not indicate that the water can percolate through the walls. The less water that will pass into the walls of either concrete or clay tile, the more lasting and durable will be the tile. Good tile should generally not take over 10 to 12 per cent of its own weight in water. There are some good clays that even when well burned take a higher absorption and are still very durable.

Hauling and distributing tile. For the smaller sizes of tile a wagon with three boxes can be used, but for the larger sizes or where the land is dry a strong hayrack is better. The size of the rack or box necessary and the weight of the load can be readily computed from a manufacturer's table of tile weights and sizes. Tile are usually packed in the car on the side, being securely wedged to prevent their shaking around and breaking. When wagons are loaded, the tile can be packed either on side or on end, but in either case they should be so packed that undue breakage will not be caused by jolting in driving over rough ground.



After University of Minnesota

FIG. 232. *Clay and cement tile which have seen long service and are as good as on the day they were laid*

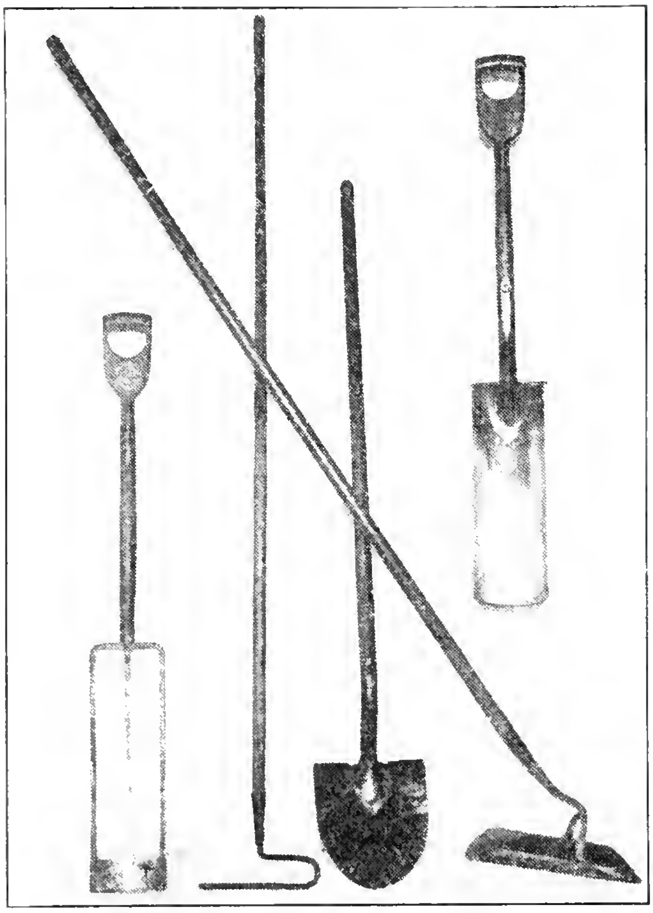
Tile often load to better advantage on end, but are subject to greater vibration. They should be unloaded in the field from the outlet of the ditch upstream, the ditches being taken in the same order in which they are to be dug. If for immediate use, tile should be strung along the line of the proposed trench placed end to end, four extras being left for every hundred feet to cover shortage and inspection (Fig. 233). In pasture fields where there is stock, or in cultivated fields where there is likely to be a delay of some weeks before they are placed in the trench, they should be unloaded in piles of twenty-five to fifty. If they are to lie out through freezing weather, or for several months before construction, it is best to place them in piles of one hundred.

After University of Minnesota

Fig. 233. *Distributing tile on the line of trench*

Some tile-layers prefer to have the tile placed at right angles to the trench. For hand trenching the tile can be unloaded within 6 feet of the right side of the stake line as one looks down. As broken tile are valuable for covering cracks and open joints, all pieces should be hauled out and scattered along the line, especially at curves and junctions. These pieces fit better if they are from tile at least 1 inch larger in diameter than the tile with which they are to be used.

Trenching. In trenching by hand a line is stretched at a uniform distance from the stake line. The edge of the ditch should come as near the stakes as it can be dug without disturbing them. This line marks one edge of of the trench. The width of the trench at the surface varies with the depth of the ditch, being just wide enough to allow the workman to stand and spade. A skeleton or muck spade is used for removing the earth. This spade has a blade 18, 20, or 22 inches in length, made of three prongs with a solid cutting edge at the lower end. A cut the full length of the blade is taken, the slice of earth cut being comparatively thin. The top of the spade is pushed slightly forward and turned to the center to break the cut loose. It is then raised and the material thrown out. The loose dirt which falls in the trench, known as *crumbs*, is thrown out by means of a long-handled, round-end shovel. The last cut of the spade reaches to within 2 or 3 inches of the grade and is just wide enough at the bottom to admit the tile. The bottom is cleaned out and dressed to fit the lower half of the tile with the tile scoop. The tile scoop is a long-handled tool, semicircular in shape, 17 inches in length, and made in sizes to fit the various tile up to 8 inches. Above that size the finishing is usually done with the long-handled shovel. In operating the tile scoop the workman stands in the trench and draws the scoop toward him (Fig. 235). The bottom of the trench behind the tool is smooth and conforms to the lower half of the tile. In trenching by hand, unless the trench is deep or the digging hard, two men work together. One takes out the top spading, and the other the bottom and finishes



After University of Minnesota

FIG. 234. *Hand tools used in tile trenching: skeleton spade, long-handled shovel, tile hook, tile scoop, solid spade*

the trench. On deep trenches there is usually a man at work on each spading depth, the trench being carried along in steps. In hand trenching the cost per rod or 100 feet includes the digging of the trench, laying of the tile, and blinding, and is customarily a fixed price for all trenches averaging 3 feet in depth or under, then a given amount is added to that sum for each inch in depth the trench averages over 3 feet. The average is found by dividing the sum of the cuts at all the stakes by the total number of stakes.

After University of Minnesota

FIG. 235. *Excavating a 3-foot tile trench*

Trenching machines. Several forms of trenching machines have been designed for sewer work. Any of these can be used for tile work where the ground is solid. By the application of caterpillar traction or by the use of very wide wheels it is possible to use these machines on soft ground. Some of them operate by a revolving wheel carrying buckets on the rim which cuts slices of earth as the machine moves ahead and deposits it on an apron which throws it to one side. Others use a ladder arrangement around which operates an endless chain carrying buckets which cut slices of earth as they come up out of the trench. These machines are economical for laying large-size tile and greatly reduce the labor necessary for the construction of large systems. In caving materials a sheathing attachment is pulled with the machine to prevent caving before the tile is in place. A crane attached to the rear of the machine may be used to lower the tile. The tile is laid by workmen. The machines are expensive and require experience and mechanical skill in operation and are suitable for farm use only when handled by contractors who make a business of ditch construction.

Grading. The grading of tile trenches is very important, and there are several methods equally good that are in common use. The method of using cross lines is as simple and satisfactory as any. The line of the ditch is marked out by stakes left by the surveyor. The stakes may be 50 or 100 feet apart. There are two stakes in a place, one with the top driven level with the surface of the ground, known as the

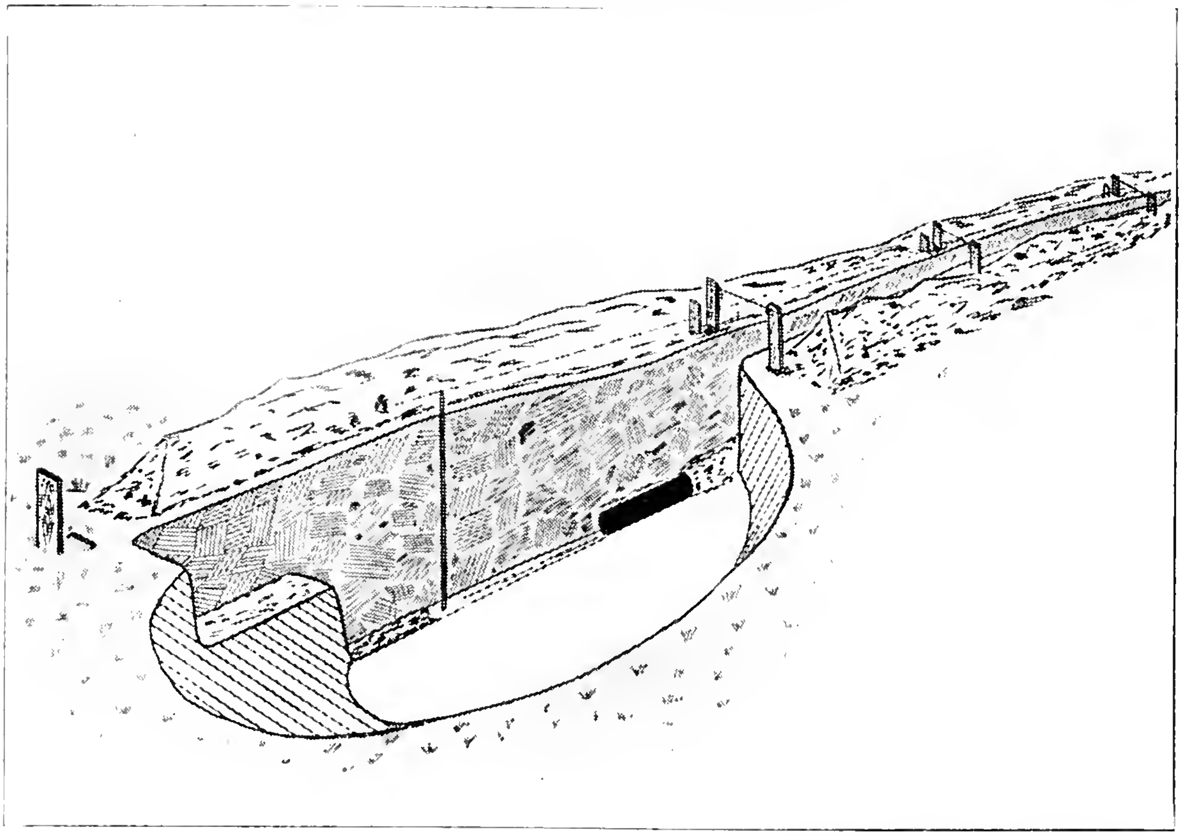


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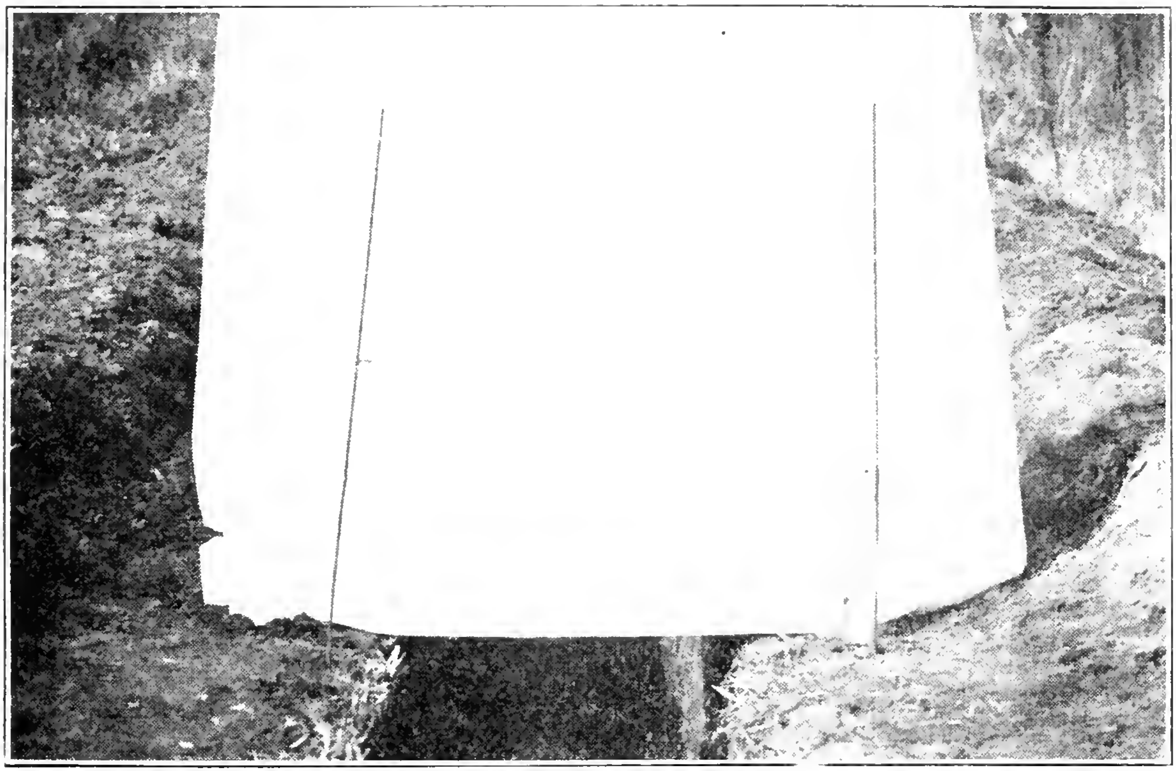
FIG. 236. *Method of grading the bottom of a trench for tile*

hub, and the other standing a foot or more above the ground, called the *guard*. The hub stake is the one from which all measurements are made. The guard stake, driven a couple of inches from the hub, gives the location of the hub as well as its number and the depth of the ditch below the top of the hub. These stakes are set and numbered and the depth of the ditch computed by the surveyor.



After University of Minnesota

FIG. 237. *Details of a string target*

To dig the ditch to the proper grade from these stakes, the depth of the ditch below the top of the hub should be subtracted from 5 feet. The difference between this depth and 5 feet should then be measured up from the top of the hub and marked on a target rod which has been driven near the hub. At this mark a string approximately ⅛ inch in diameter should be securely tied around the target rod and then drawn across the trench and tied to a target rod on the other side, a carpenter's level being used to keep the string level while it is being tied to the second rod (Fig. 237). The string should be drawn tight and the rod should be firm enough to prevent the string from changing its position after it has once been fixed. Similar strings should be placed at not less than two more stakes. The line of sight across these strings will be in a line which is parallel to and 5 feet above the grade line of the ditch. The tile-layer, by holding a rod 5 feet in length on the bottom of the ditch, can determine if the ditch is at the right grade by sighting across the upper end of the rod at the strings. If it is in line with the strings, the ditch is at the proper grade. Hence, by testing every foot of the bottom of the trench with this rod, and sighting over the top of the rod at the three strings, he can construct the bottom of the ditch to the exact grade. When the strings are being put up, if the three are not in line, it shows that there has been an error, either in the surveying or in figuring the height of the strings, for the three will be in line if the work is correct. Hence this method of grading the bottom of the ditch is a check on the accuracy of the survey.

Laying tile. The laying of the tile should begin at the outlet and be continuous upstream. For convenience, the tile should have been distributed close to the trench so that they can be reached by the tile-layer without loss of time. In being laid the tile should be turned until they fit tightly on top, the open space being left on the under side. The fit is usually best obtained in crooked tile when the bowed side of the tile is turned up. When a crack of over ¼ inch in width is left, it should be neatly covered with a piece of broken tile.

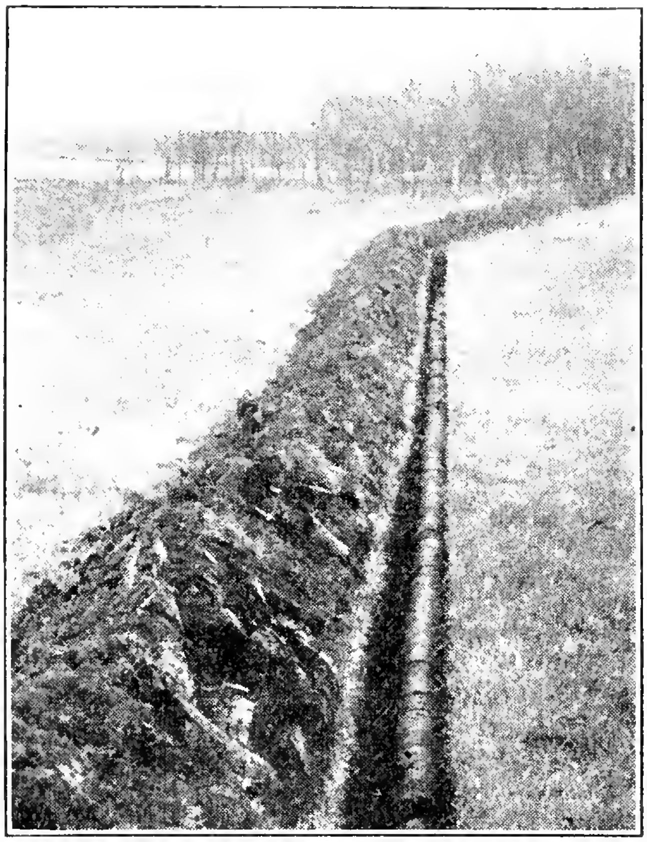
Tile up to and including 6 inches in diameter are usually laid with a tile hook (Fig. 238), the workman standing on the bank of the trench. The tile is picked up with the hook, lowered into the trench, and turned on the hook until it will fit, when it is laid in position. A sharp rap with the hook on the end of the tile after it is laid often causes it to fit the preceding tile more snugly. Tile hooks are not carried in stock by dealers, but they can readily be made by a blacksmith. The hook is made of one-half inch round iron, the long part being 9 inches and the short part 4 inches in length. The bend is of sufficient width to admit the wall of the tile without binding. The handle is a rake handle.

Small sizes of tile are sometimes laid by hand, the workman standing on the tile already laid. In shallow trenches it is difficult to reach down to the grade line, and in a soft bottom there is danger of displacing the tile by the weight of the workman. In trenches where the depth is so great that it is difficult to throw the earth out, or where the trench is caving, the workman who finishes the bottom lays each piece of tile as rapidly as the bottom is prepared and throws the last spading of earth back on it. The tile-layer should not stand on the finished bottom while tile are being laid. When large sizes of tile are being laid, where it is necessary to work backward in the trench and lay the tile the finishing work should be done at the same time, each piece being put in place as rapidly as the bed is prepared for it.

After University of Minnesota

FIG. 238. *Laying tile with a tile hook*

Tile, when laid in the trench, should have even joints, with no sharp bends, and present the general appearance of a continuous pipe. The tile-layer should carefully inspect the tile as he proceeds with the work and reject all which are cracked, soft, or so ill-shaped that good joints cannot be made. Defects can usually be noticed when the tile is picked up with the hook.



After University of Minnesota

FIG. 239. *Tile laid in trench ready for blinding*

Junctions and curves. The incoming flow of water should strike the stream in the main at an angle of approximately 30°. All tile factories now make junction tile, with the branch set at the proper angle, and these junctions should be used whenever they can be obtained. However, good junctions can be made of straight tile cut and fitted together. Unless the grade prevents, the top of a branch tile should be as high as the top of the main tile, at a distance from the main equal to the length of the curve which joins the branch to the main. Bends in tile-laying should be made by smooth regular curves, with outside joints covered with pieces of tile 1 inch larger in diameter than the tile laid, or the end can be cut off the tile for the inside of the curve if the end of the tile is caught between the jaws of a monkey-wrench and pressed down on the handle.

Inspection. After being laid, tile should be inspected by the landowner to see that the joints are tight and tile laid straight in the trench. It is also desirable to have an inspection by the engineer to determine whether the tile is laid to the required grade. This can be determined by the landowner when there is a small quantity of water running. A measurement at the hubs will determine the depth, and the flow of water through the pipe will indicate the grade.

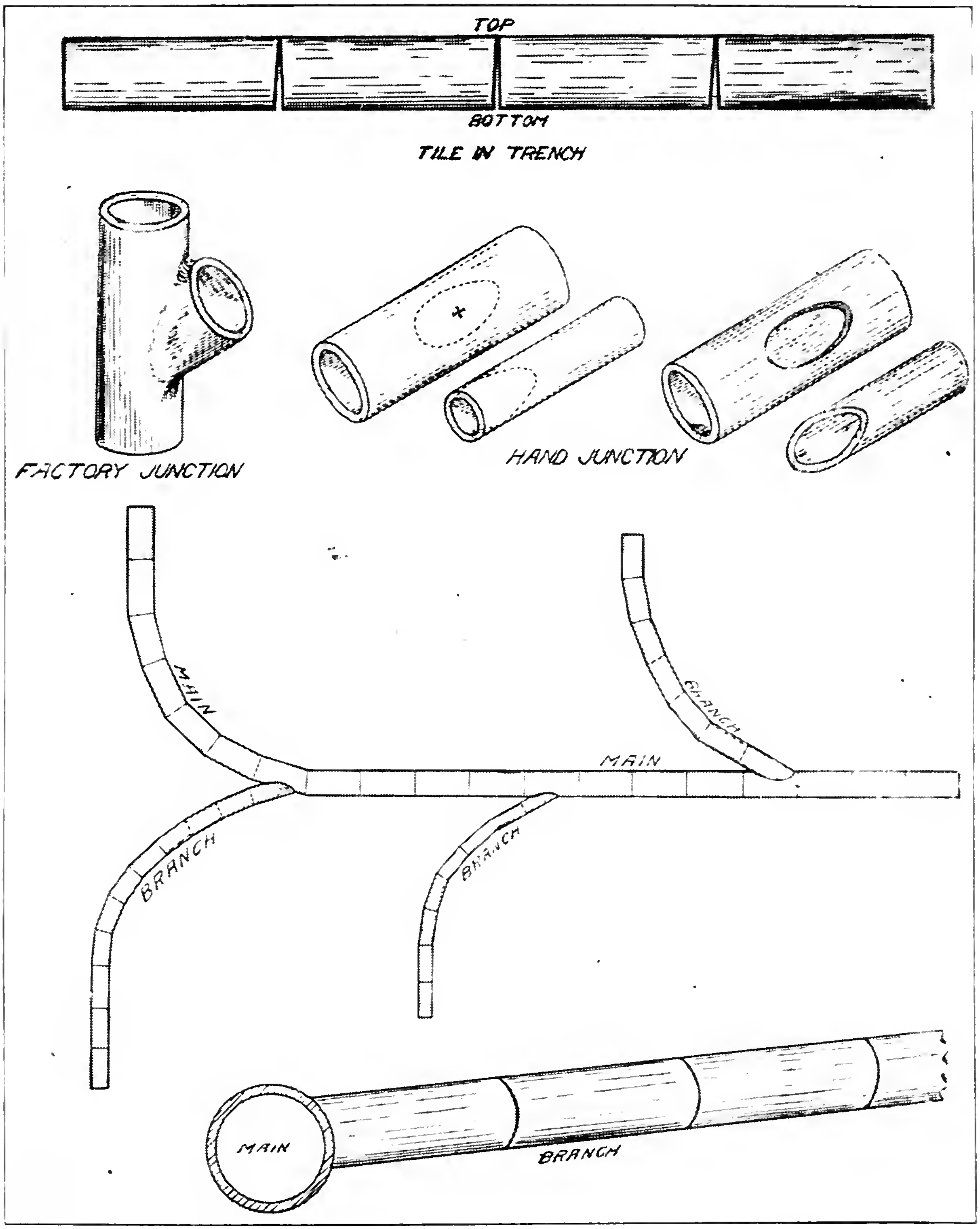


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FIG. 240. *Details of tile construction showing the position of the tile in the trench, junctions, curves, and branches*

Blinding. After the tile are laid a covering of 4 to 6 inches of earth is put on to hold the tile in place. This covering is called *blinding*, and is put on by the workman walking astride the trench and cutting down the earth below the surface from either side with a tile-spade, taking care not to disturb the tile and batted joints (Fig. 241).

After the University of Minnesota

FIG. 241. *Blinding tile*

Backfilling. The refilling of tile trenches is accomplished in several ways. Short sections, in the vicinity of fences or buildings, are filled by hand, the tools used being a shovel or ordinary spade. Where the material is soddy or sticky, a potato fork or other heavy-tined fork can be used to advantage. Coarse sod can be conveniently handled by a fork bent in the form of a hook. Where a team can be employed short sections can best be filled by two men with a team and slip scraper. Where there is a line of trench free from obstruction, the most economical method of filling is by means of a plow.

Tile outlet. The action of the tile is dependent upon the distance of the outlet above the surface of the water at the outlet channel and not the distance above the bottom of the outlet ditch. So long as the water of the outlet is below the tile, the drain will act to its full depth. If the water rises above the outlet, drainage will take place only above the elevation of the water surface, and if it becomes higher than the bottom of the swales in the area drained, water will stand on the surface of such places until it falls at the

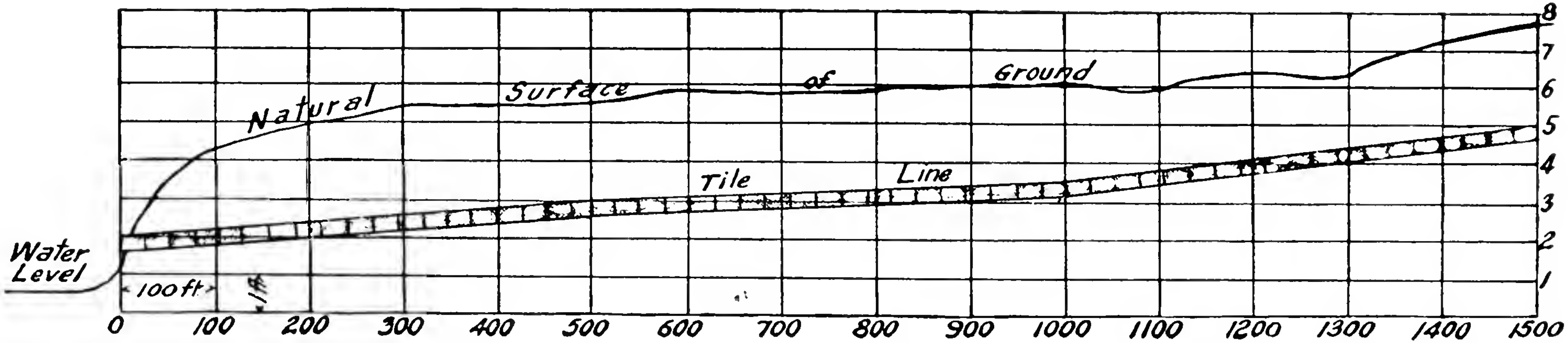

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FIG. 242. *The relation of the tile line to the ground surface*

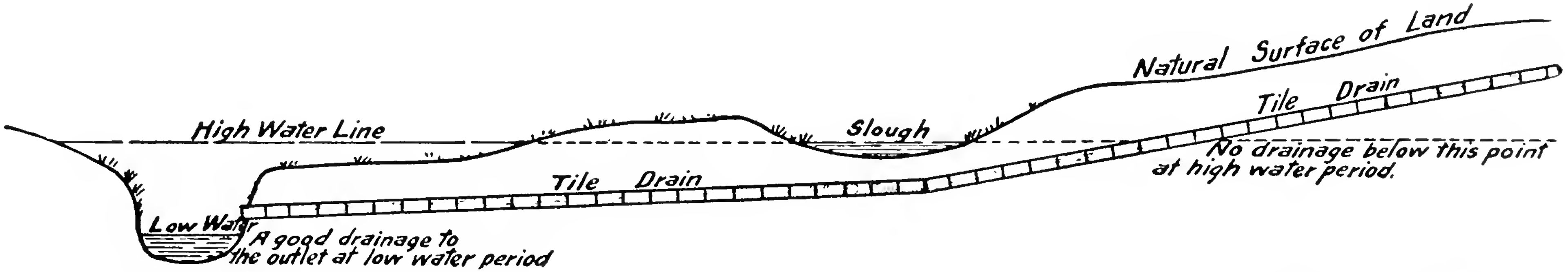

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FIG. 243. *Effect of high water on tile drain. At low-water period there is good drainage to the outlet, but at high water there is no drainage below the dotted line. Consequently the advisability of using this creek as a tile outlet depends upon the number of times a year the water rises to the dotted line and the length of time it remains at that height*

outlet. Moving water does not injure field crops, and if standing water is removed inside of twenty-four hours, there is no harm done. In northern latitudes it is necessary to have the tile outlet so located that it will be free from water at the freezing period.

It is essential that where a tile drain outlets into an open ditch the outlet end be protected in some manner. As the tile are only a foot in length, the end joint is easily washed out, or may be destroyed by scaling when exposed to air and frost. As soon as the end pipe is destroyed the next one above is subject to the same destructive influences, thus interfering with the outlet and often preventing the proper discharge and causing sediment to settle. A protective structure for a tile laid into an open ditch is commonly spoken of as a *tile outlet.*

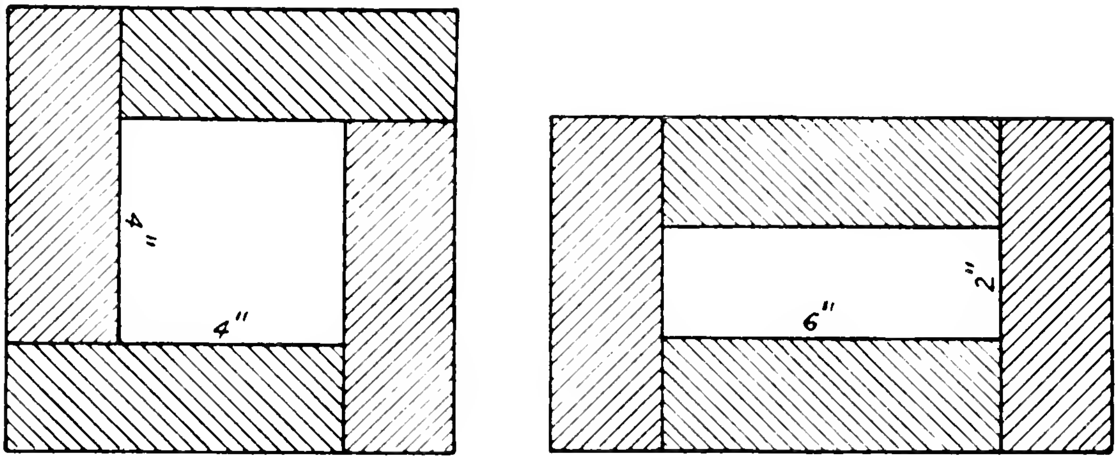

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FIG. 244. *Difference in inside area caused by different methods of nailing together 2" × 6" plank for tile outlet projection*

The practice in the past has been to make this outlet of wood, protecting the opening with a wire screen to prevent the entrance of animals. The use of the screen is being discontinued in many localities, and the wooden boxes are being replaced by pipe made of very hard burned clay, metal, or concrete. Where a screen is used it offers some obstruction to the flow of water, and the end of the pipe should be at least 1 inch larger than the drain before the screen is reached. Pipes or boxes should be carefully tamped in and a good junction made with the tile. Where practicable the last tile should extend 2 inches into the outlet protection. If the water begins running around the outside of the outlet, it is likely to be washed out. Until the trenches have thoroughly settled and the slope of the ditch has set in grass, the loose dirt will slip down in front of the outlet. If a structure in the nature of a wall is built at the outlet, there will be less trouble from this source. During the period of the dry season grass and leaves will blow through the screen, and when the water begins to run, this drift will wash down and lodge against the screen, causing an obstruction. The outlet will thus require some attention to keep it in working order.

Cleaning out tile. When tile becomes clogged, the approximate location of the obstruction may be determined shortly after a rain. The ground will dry out up to the point where the tile is not working, while above the obstruction the soil will be filled with water. The line between the wet and dry soil will determine the location of the obstruction. Holes can be dug down to the tile and two or three joints taken out. Lath can be inserted one at a time and fastened by small nails and run back into the tile a hundred feet or more. If other holes are dug, connections may be made underground with the lath and these be worked back and forth; if there is some water in the tile, silt and other deposits may be stirred up and the water will carry them out. The lath can be carried down through the line of tile by means of holes dug at sufficient intervals so that the string of lath will pass from one to another. A bunch of hay or straw tied in a bag and pulled through the tile will clean it out effectively if the deposits are not too solid.

Injury by freezing. A good quality of tile will not be affected by freezing if laid to grade so that water cannot stand in the tile. Tile holding water to a depth equal to one-fourth of its diameter can be frozen many times without serious injury, but if the water reaches the horizontal diameter, or the tile is three-fourths full of water, freezing will crack the tile and possibly destroy it because of the expansion of the ice. Soft or porous tile which absorbs a large percentage of water may be destroyed by freezing and thawing a number of times, but hard tile is not destroyed in this manner. Continuous dripping of water in cold tile may fill it with ice without bursting it, or where the earth is well packed around the tile it may crack from freezing and not collapse. It cannot be assumed that because a tile drain is in good working condition it has not been affected by freezing. Tile drains in cold climates, with good outlets and laid to grade, will not be injured when laid above the frost line.

Roots of trees. Roots of trees and plants are sometimes the cause of annoyance in tile drains, and there are many conflicting opinions in regard to the injury done by them. Where water ceases to flow in the tile as soon as the surrounding land dries out, there is little danger of obstruction, as the dry tile offers no attraction to the roots; but if the tile carries water far into the dry season, the roots will go into it in search of water. While a wet-land tree, as well as some others, may grow along a tile without forming an obstruction, for the reason that there is plenty of water in the soil at the time the tile is running, wet-land trees, especially willows, should be regarded with suspicion when near a tile drain. If it is not desirable to destroy the trees, the joints of the tile should be carefully cemented past the point where small roots can be found in the ground.

OTHER METHODS OF DRAINAGE

Levees. Lands along a stream which are lower than the ordinary high-water plane of the stream can be made productive only by being protected from overflow. Where the overflow is due to an insufficient or an obstructed channel, relief may be had by means of a new channel of a size that will carry the water below the ground surface. Where it is practicable to construct such a channel, it is the only method that should be used. If a great area of overflowed land lies along a stream in which the volume of water is so large at flood time that it is impractical to attempt to carry it in a channel, it is necessary to resort to artificial banks or levees to prevent the water from spreading beyond reasonable limits when it rises higher than the natural banks. Large areas of bottom lands have been protected from overflow by levees along the Illinois, Mississippi, and other rivers. In reclaiming lands that are subject to overflow, it is essential that the levee system be planned and located by an engineer experienced in levee work (Fig. 245).

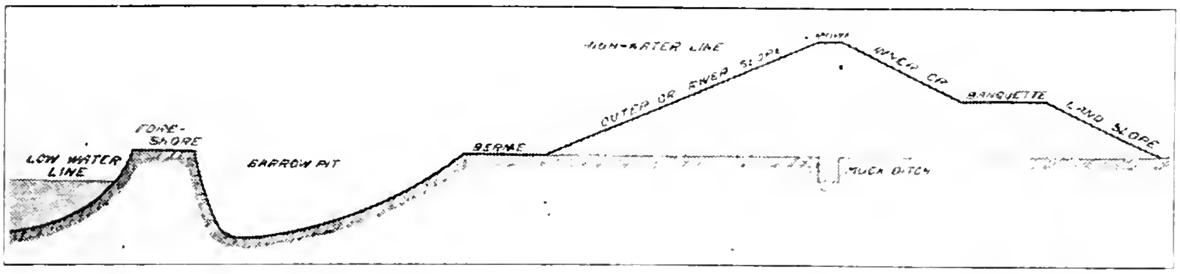

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FIG. 245. *Typical cross section of a levee. The technical names of the various parts are indicated.*

Well drainage. Drainage by sinking wells has been given wide publicity, but without compensating results. In rolling country deep depressions of small area are objectionable from an agricultural standpoint, and to remove them by ordinary methods of surface drainage is very expensive. The sinking of wells to drain these small areas has been attempted and occasionally gives satisfaction, but experience indicates that even where results are obtained for a short time, the capacity of the well for taking water gradually decreases until it becomes ineffective.

The principle of well drainage is the same as that of surface drainage. Water flows by the action of gravity, and there must be some channel through which it can escape. If the lower soil strata are composed of open seams or large fissures in the rock, such as occur in limestone formations, or if there is a bed of gravel or sand which has a drainage outlet in some hillside or stream bank, there will be a passage for the water underground, and if the

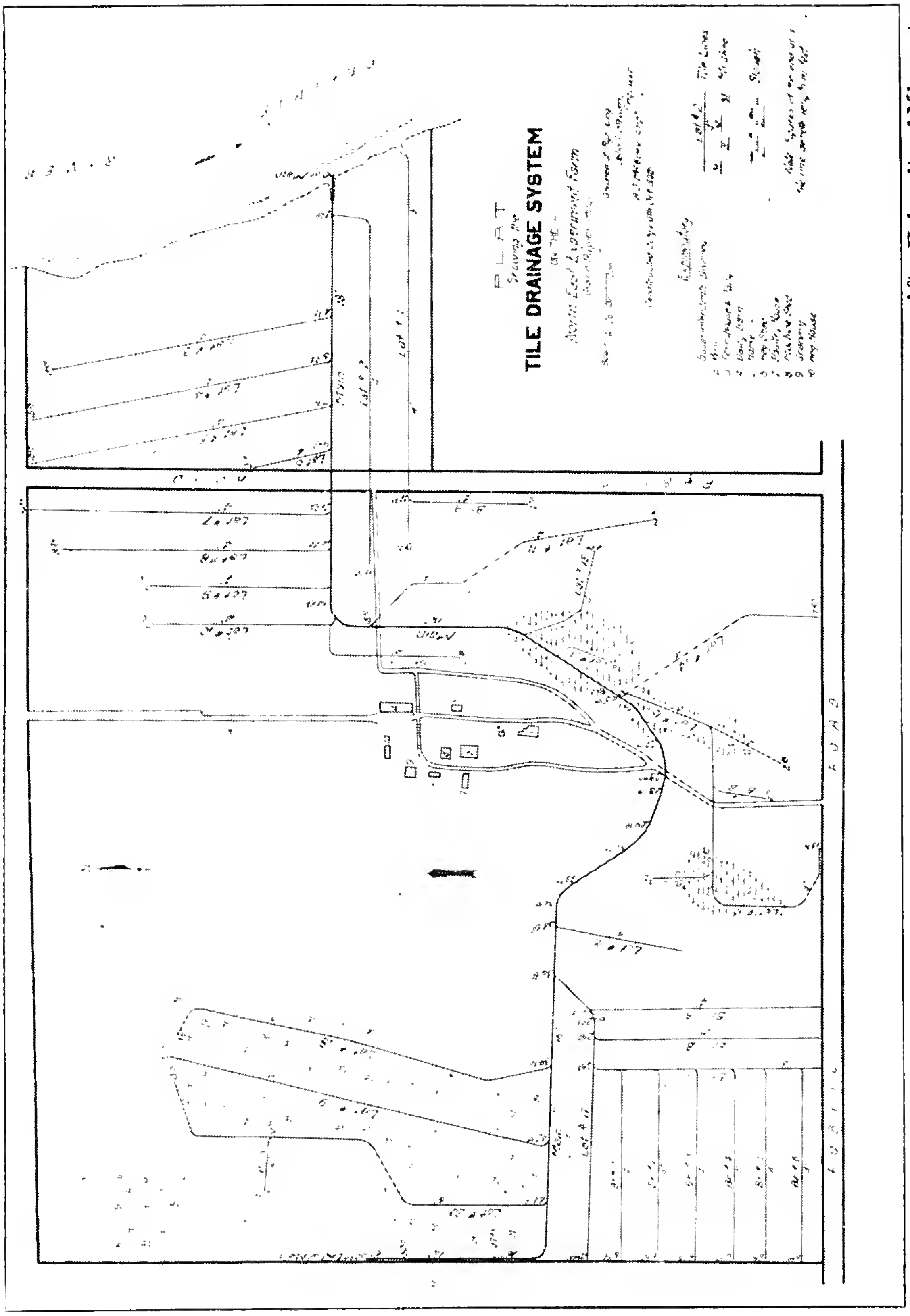

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FIG. 246. *Tile drainage system for both rolling and flat land. The lines indicate the tile drains; heavily shaded portions indicate sloughs, and lightly shaded portions muskeg. Figures at the end of the line denote length in feet.*

small slough is connected into one of these passages by means of a well, the water will flow downward and escape. There is no practical method of determining on the surface where to sink a well, how deep to go, or what the final results will be. The conditions in a water supply and a drainage well are reversed. In the former the fine sand and silt are drawn up and ejected by the pump, tending to make the flow freer with use; but in the latter the silt and fine sand carried in the drainage waters are carried backward into the strata, and the continuous action of the water pushing outward from the well compacts and solidifies the material and in a short time it is closed to the passage of water. The well then ceases to operate as a drain. The drainage of large areas of surface water into underground strata is objectionable from the standpoint of sanitation, as there is danger of contamination of the water supply.

FINAL MAP

On the completion of a farm drainage system, a plat should be made showing the location and size of all drainage work completed. This is not as important for open ditches as for tile drainage. In a few years' time it may be impossible to determine on the surface where the tile was laid, and when the land is sold the purchaser may demand a plat showing the underdrainage system. In many soils it is costly work to plat a tile drainage system that has been laid for several years, and there is always an uncertainty as to the exact location and size. Real estate men recommend, in drained areas, filing with the county recorder a certified plat showing underdrainage on individual farms.

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PART IV. BUILDING EQUIPMENT

CHAPTER XV

BUILDING CONSTRUCTION

PREPARATION OF THE SITE

The first step in the construction of a building is the preparation of the site for the foundation. Clearing and drainage are accomplished in precisely the same manner as on the remainder of the farm, but excavating and grading require special work.

Excavating and grading. In excavating, the unit of measure is usually the cubic yard. If the surface is uneven, it can be cross-sectioned and the elevation of the different points taken by means of a level. In this manner an average is found for each section. The size of the section will vary according to the unevenness of the surface, such as 10 feet, 50 feet, or 100 feet. If the slope is regular, the levels may be taken at the corners only. Allowance must be made for extra room to work around foundations, and if the excavation is to be deep, some provision must be made to keep the banks from caving.

The cost of excavating depends upon the nature of the soil, condition of the site — whether level, containing rubbish, trees, or rock — and the distance to haul. Earth increases in bulk 10 to 50 per cent in loose state, but when packed occupies less than the original space. These matters should be considered in the letting of contracts for hauling and filling.

The operation of excavating consists of: (1) loosening; (2) shoveling or loading; (3) hauling; (4) dumping and grading.

Loosening with pick:
1 man 10 hours
Hard clay...15–20 cubic yards
Loam....... 20–50 cubic yards

Loosening with plow:
2 men 10 hours, 1 team, and 1 plow
Hard clay...200–300 cubic yards
Loam.......400–600 cubic yards

Shoveling or loading into carts (loosened earth):
1 man 10 hours
Heavy clay....15–20 cubic yards
Loam or sand..20–25 cubic yards

Moving with wheelbarrow[1] (loading own barrow with loosened dirt):
1 man 10 hours
Haul 100 feet..15–20 cubic yards
Haul 500 feet.. 5–8 cubic yards

Hauling with carts[2] (loosened earth):
1 man 10 hours and 1 team 10 hours
Haul 200 feet... 30–40 cubic yards
Haul 1,000 feet..12–18 cubic yards

Moving with drag or slush scraper[3] (loosened earth):
1 man 10 hours, 1 team 10 hours, 1 scraper
Haul 100 feet..75–80 cubic yards
Haul 200 feet..40–50 cubic yards

Moving with wheel scrapers[4] (loosened earth):
1 man 10 hours, ½ man 10 hours, 1 team 10 hours, 1 scraper
Haul 200 feet..75–100 cubic yard
Haul 500 feet..40–50 cubic yards

It is economical to use a drag or slush scraper up to a distance of 100 feet; wheelbarrow, 200 to 250; wheel scraper, 500; dump cart and wagon, 600. Above this distance, a dump car should be used.

[1] A man averages 2½ miles per hour, or 220 feet per minute. Loading, dumping, turning, etc., require 2½ minutes per load. A wheelbarrow holds 3–4 cubic feet, or 1/9 to 1/7 cubic yards.

[2] A team averages 2½ miles per hour, or 220 feet per minute. Dumping and turning require about 4 minutes per load. A dump cart holds 18 to 22 cubic feet, a wagon 27 to 45 cubic feet, a dump car 27 to 81 cubic feet.

[3] A slush scraper holds 3 to 7 cubic feet.

[4] A wheel scraper holds 10 to 17 cubic feet.

Weight of Soils per Cubic Yard

Loam	2,100–2,400 pounds
Clay	2,400–2,800 pounds
Sand	2,500–3,000 pounds
Gravel	2,600–3,300 pounds

THE BASE

Foundations. The foundation is that portion of a structure which serves as a base upon which to erect the superstructure. It may be all or in part below the ground. The object of any foundation is to form such a solid base that no movement shall take place after the superstructure is erected. Nearly all structures will settle to some extent unless built on solid rock, as soils become compressed under the weight of heavy buildings. Care should be taken that a foundation is evenly loaded and properly proportioned in order that settling may be uniform and cracks thereby avoided. A 12-inch wall is considered the thinnest that can be built in any but very short lengths and small depths. Where city ordinances cover this point, a 12-inch wall is the minimum, although an 8-inch concrete wall would be amply strong for most residences. Rubble stone wall is generally 16 to 20 inches thick. A concrete wall is usually the most satisfactory, because it can be made the minimum thickness and placed by unskilled labor. Brick is satisfactory where a hard-burned quality of brick is to be had. Hollow tile are amply strong if full-mortared joints are used. Water will find its way through all of these walls with the exception of the monolithic concrete.

Number of Tons Which a Square Foot of Different Soils in Their Natural State Will Support

Material	Minimum Tons per Sq. Ft.	Maximum Tons per Sq. Ft.
Clay—dry	4	6
Clay—moderately dry	2	4
Clay—soft or wet	½	2
Sand—well compacted	4	6
Rock	10	200

Footing. It is often necessary to use a footing or extension in width of a foundation in order to bring the load within the allowable limit of the soil. In determining the width of footings, it is necessary to determine the total weight of the building, together with the maximum load which the building may contain at any time.

Basements. Basement walls are in most cases the same as foundation walls. The floor may be tamped earth or clay, but brick or concrete is much more satisfactory. Walls dividing the basement into smaller rooms may be of the same material as the outside walls, although light frame partitions under ordinary conditions meet all requirements. Either the brick work of the chimney will extend to the basement floor or provision must be made for a supporting structure.

THE SUPERSTRUCTURE

Walls. Walls may be of various kinds, as follows:

Frame. The construction of frame walls has become so standardized that a discussion of methods is here unnecessary. Estimates as to the labor and quantity of material to be used would vary with individual conditions.

Stucco. Stucco is applied as a plaster upon a metal lath or expanded metal and common galvanized mesh, upon ordinary wood lath, or upon common lath and insulating material. The life of the stucco is contingent upon the bond which can be made between the plaster and the surface of the building. In the case of metal lath and wire mesh, the life of the covering is

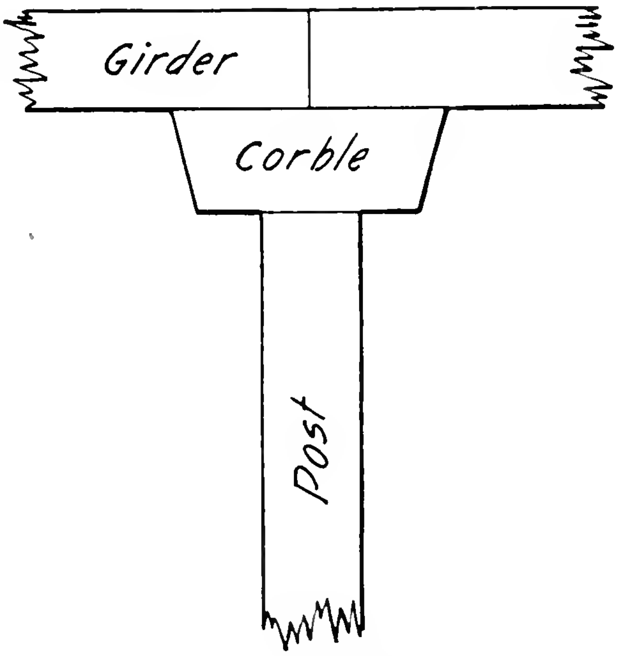

FIG. 247. *Typical support in timber construction*

dependent upon the rusting out of the metal, which is nailed or stapled to the building. If the fastening is perfect, the life of the stucco may be considered rather indefinite. When applied to tile or brick, the bond is harder to make, but if it is well made the finish is altogether durable. To make this bond on tile or brick it is necessary to have the surface clean and free from loose particles, and the surface should be given a paint coat of neat cement just ahead of the man with the trowel. A defective stucco job is very difficult to patch, owing to the trouble in matching colors.

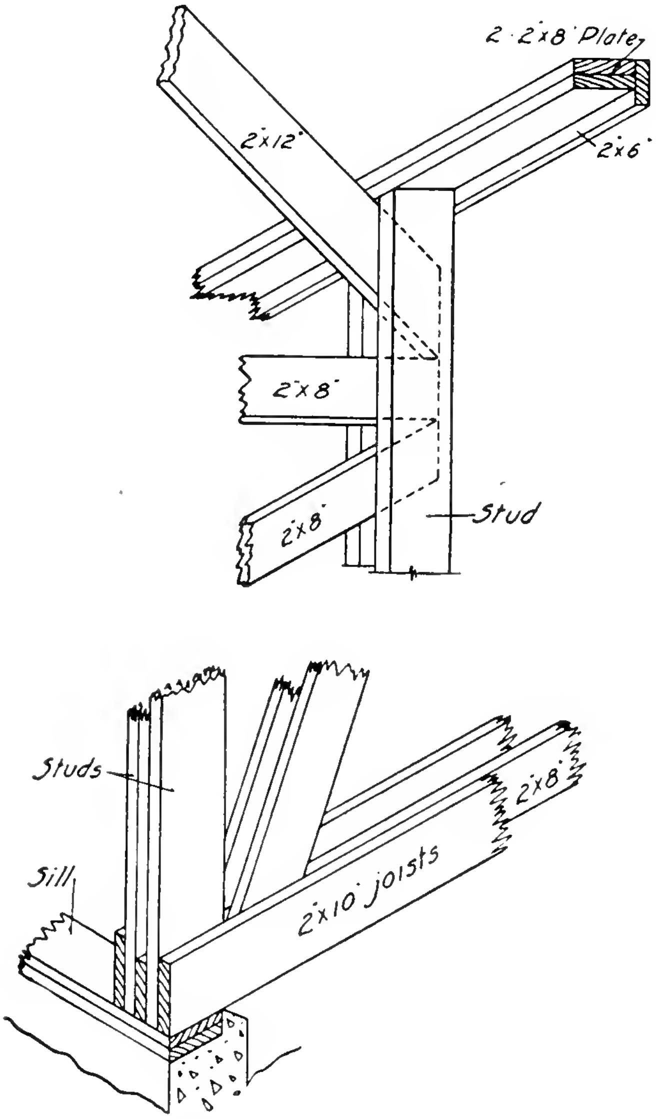

FIG. 248. *Details of construction at plate and base of plank truss*

Galvanized iron. Galvanized iron may be used on the outside of some buildings, such as barns or sheds. It may be had in plain sheets or corrugated. It is subject to attack from both sides, the weather from without and the condensation due to animal heat from within. It is made of sheet steel, and the galvanized protection is very thin. It may be had in sheets having corrugations 2½ inches center to center, although other styles are obtainable. The gauges generally used for roofing are Nos. 20 and 22, U.S. Standard. The sheets are made in 5-, 6-, 7-, 8-, 9-, and 10-foot lengths and wide enough to cover 24 inches when laid with a lap of either 1 or 1½ corrugations. The end lap may be from 1 to 6 inches.

Tin. Tin is a thin steel plate coated with a covering of tin. The size of stock sheets ranges from 20 inches by 38 inches in gauges 30 to 26½. It is sold by the box.

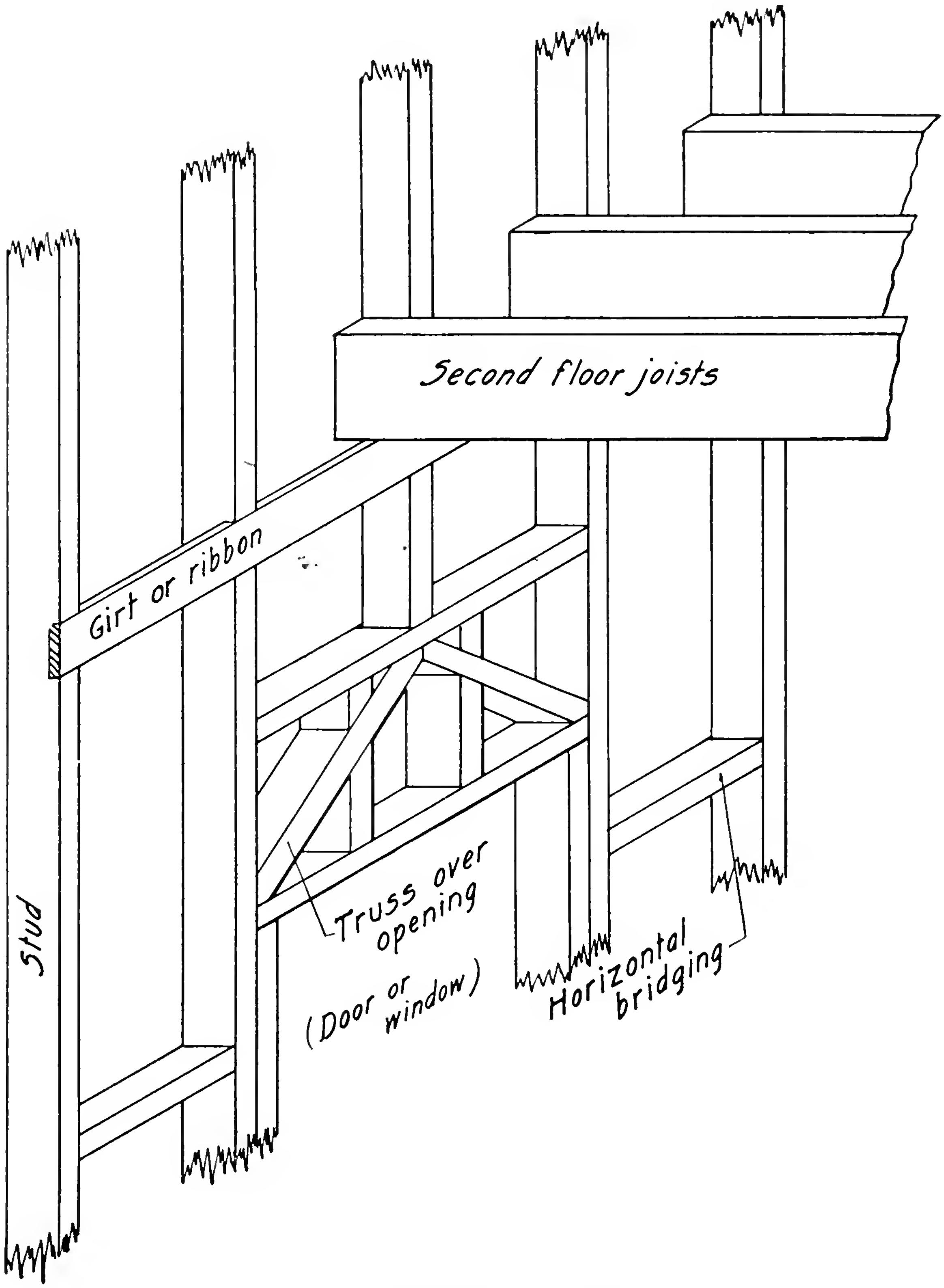

FIG. 249. *Typical frame construction*

Galvanized iron is made of mild steel or of ingot iron. Iron costs about one-half more than steel.

Brick. Bricks are sold by the thousand. Brick work is measured and calculated on the basis of a superficial foot of finished wall.

NUMBER OF BRICK REQUIRED PER SQUARE FOOT OF SURFACE WHERE A 3/8-INCH MORTAR JOINT IS USED

Thickness of Wall	Bricks per Square Foot
8- or 9-inch	15
12- or 13-inch	22½
16- or 17-inch	30
4- or 4½-inch additional wall	7½

No allowance is made for openings of less than 80 square feet.

One man can lay 60 pressed brick per hour, or 120 to 175 common brick. Ordinarily one helper is provided for each bricklayer, but on thin walls where pressed brick is used, one helper for each two bricklayers is sufficient.

To lay 1,000 common brick, it requires one barrel of lime (which is equivalent to 3 bushels) together with 5/8 yard of sand. If cement mortar is used, 1½ barrels of cement and 5/8 yard of sand are required. This makes a 1 to 3½ mixture. It is difficult to lay brick in pure cement mortar. For this reason it is common to use a cement lime mortar in the proportion of 1 lime, 2 cement, and 6 sand. This requires 3 bushels of lime, 1⅛ barrels of cement, and 5/8 yard of sand. Pressed brick require less mortar than the more irregular shapes. A colored joint in brick work costs about $1.00 per thousand extra.

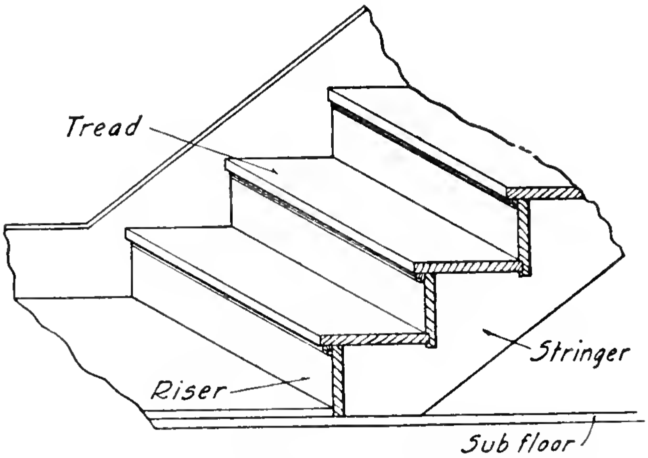

FIG. 250. *Stairway, using rabbited risers*

One thousand brick weigh 5,000 to 5,500 pounds and occupy 43.2 cubic feet.

Hollow tile. Hollow tile are laid in the same manner as brick. They are now made with ample strength to carry all loads except where a beam or joist may be placed upon them. When it is necessary to place beams and joists upon hollow tile walls, the beams or joists should extend over the whole width of the wall up to 8 inches. It may be necessary to make the wall solid with concrete or fill the tile with concrete for one, two, or three courses below the point of bearing. This, however, is seldom necessary in farm buildings. If hollow tile is used for footing or foundations directly exposed to the weather and frost, it is advisable to select the hard-burned tile for this zone. There is a great deal of difference in the burning of clay products.

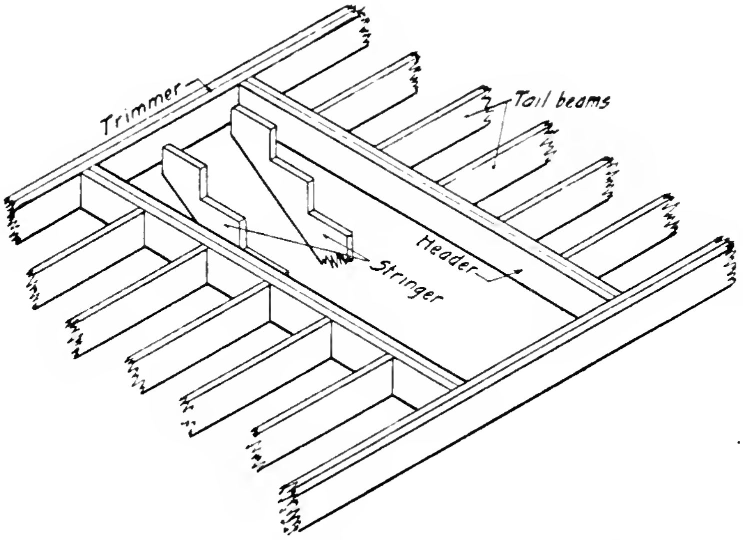

FIG. 251. *Stair well and surrounding members*

Windows and doors. In house construction both windows and doors are purchased ready to hang. Barns and other outbuildings may have homemade doors, but rarely a window constructed by the carpenter.

Windows. Window sash are made in three thicknesses: 1⅛, 1⅜, and 1¾ inches. The 1⅜ thickness is what is known as standard. It is used for all residences and most barn construction. It is heavy enough to carry the ordinary size panes of glass. The 1⅛ thickness is used for cellar sash sizes. The heavy sash is used in large buildings, where greater strength is required. Unless otherwise specified, the 1⅜ thickness is always supplied, except in the small cellar sash sizes. A window is designated by the size of the glass used in its make-up. If a check-rail window is used, the minimum number of lights of glass is two, and it would be designated as "26× 30, 2-light check-rail window." If the make-up uses small panes of glass, the designation includes the size of the panes and the number. A window frame is made to accommodate the sash. It is always cheaper to specify window sash which are known as stock sizes. They are proportionately cheaper and can usually be obtained from warehouse stock.

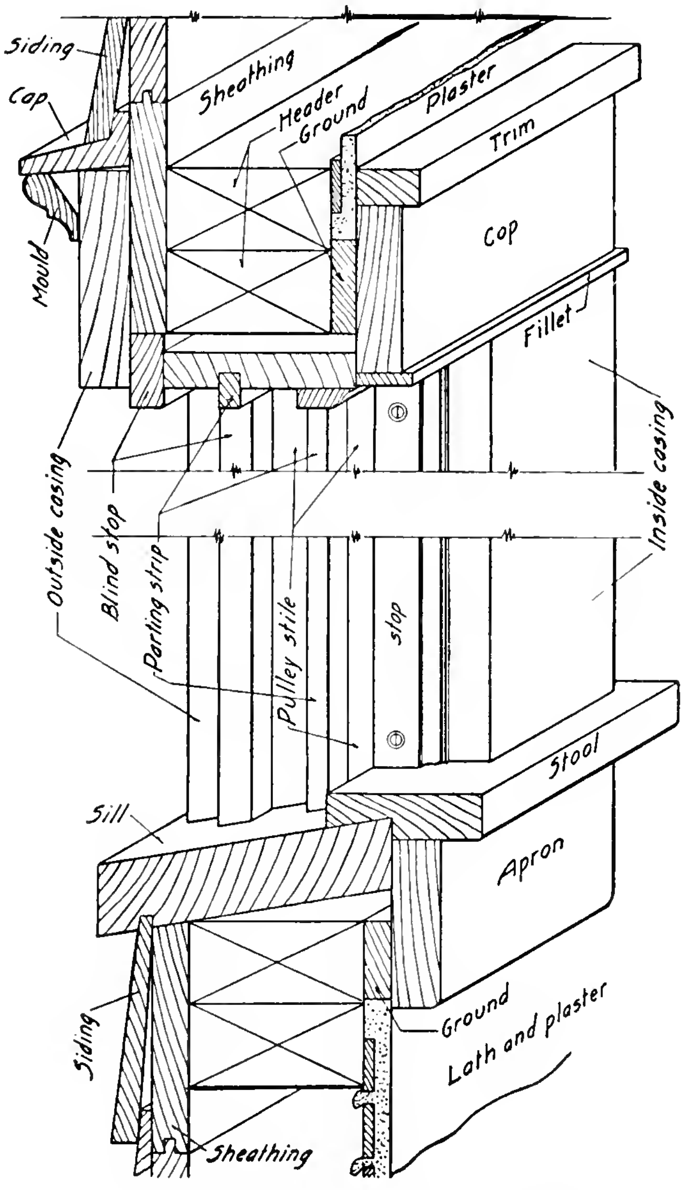

FIG. 252. *Typical window-frame construction in place*

Doors. Doors are stocked in 1⅛-inch, 1⅜-inch, and 1¾-inch thickness. They are made up solid and veneered. A well-made veneered door is better than a solid one. Practically all of the hardwood doors, including birch, are veneered. For an outside door, in a house, it is the best policy to use one that is finished on both sides with the same veneer stock, although it may not always agree with preconceived ideas of finish. The outside door is subject to extremes of temperature, and the characteristics of two different woods on two sides of a door panel often result in a warped or cracked panel.

Roofs. The roof types most used in the construction of farm buildings are: shed, broken gable, gable, curb or gambrel, half-monitor, full-monitor, hip, and mansard. (See Figs. 253 and 254.)

Shed roof. The shed roof can be used on buildings up to 18 feet in width that do not require walls of uniform height. It is suitable for single corncribs, granaries, machine sheds, chicken houses, hog houses having a single row of pens, and other minor buildings. When this roof is used on a building that is protecting animals, the high side should be toward the south. On a building that is used for storage the low side should face the direction of the prevailing winds and severe storms.

Broken gable. The broken gable can be used on buildings up to 28 feet in width and should face in the same direction as the shed roof. This type of roof is suitable for machine sheds and chicken houses.

Gable. The gable roof with or without dormers is used in buildings of any size that require walls of uniform height and is the common form for all of the larger farm buildings. In localities of heavy snowfall the ridge of the roof should run north and south in order to facilitate the melting of the snow by the sun.

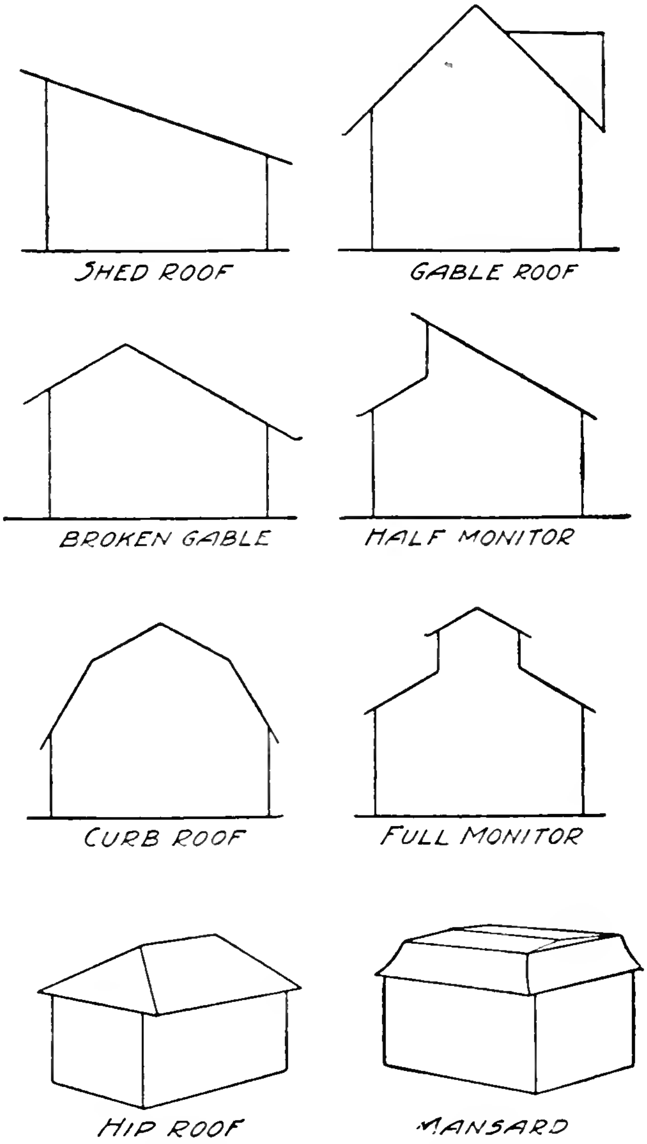

FIG. 253. *Types of roofs*

Curb, or gambrel. The curb, or gambrel, roof can be used on large buildings where a maximum of storage capacity under the roof is required. It is the most desirable roof for barns requiring hay storage. The ridge should run north and south.

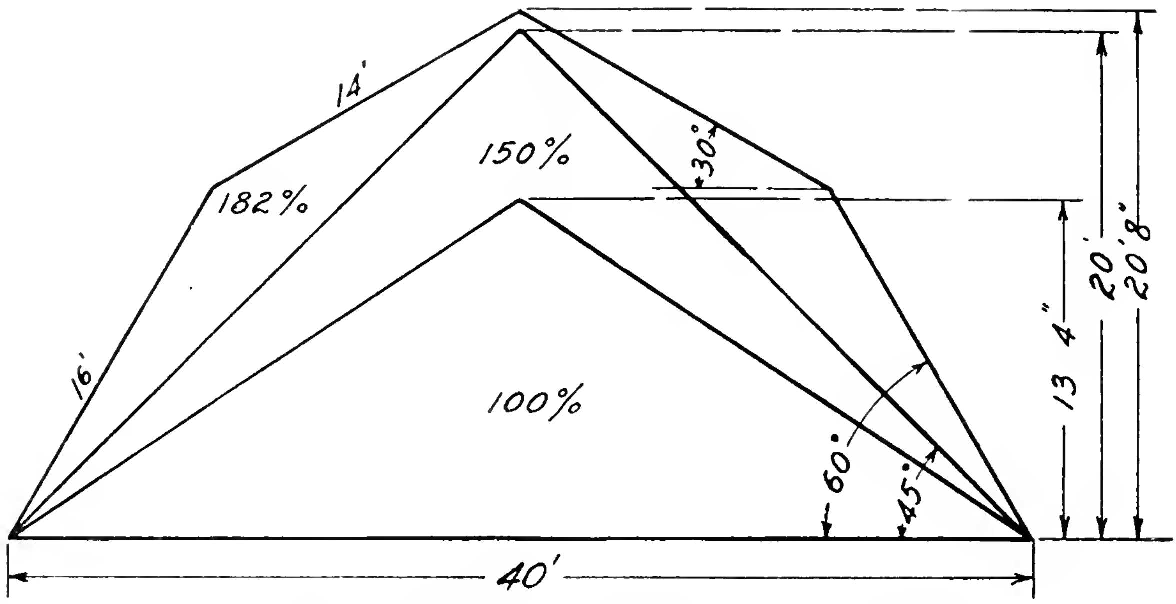

FIG. 254. *Relation of roof type to storage capacity*

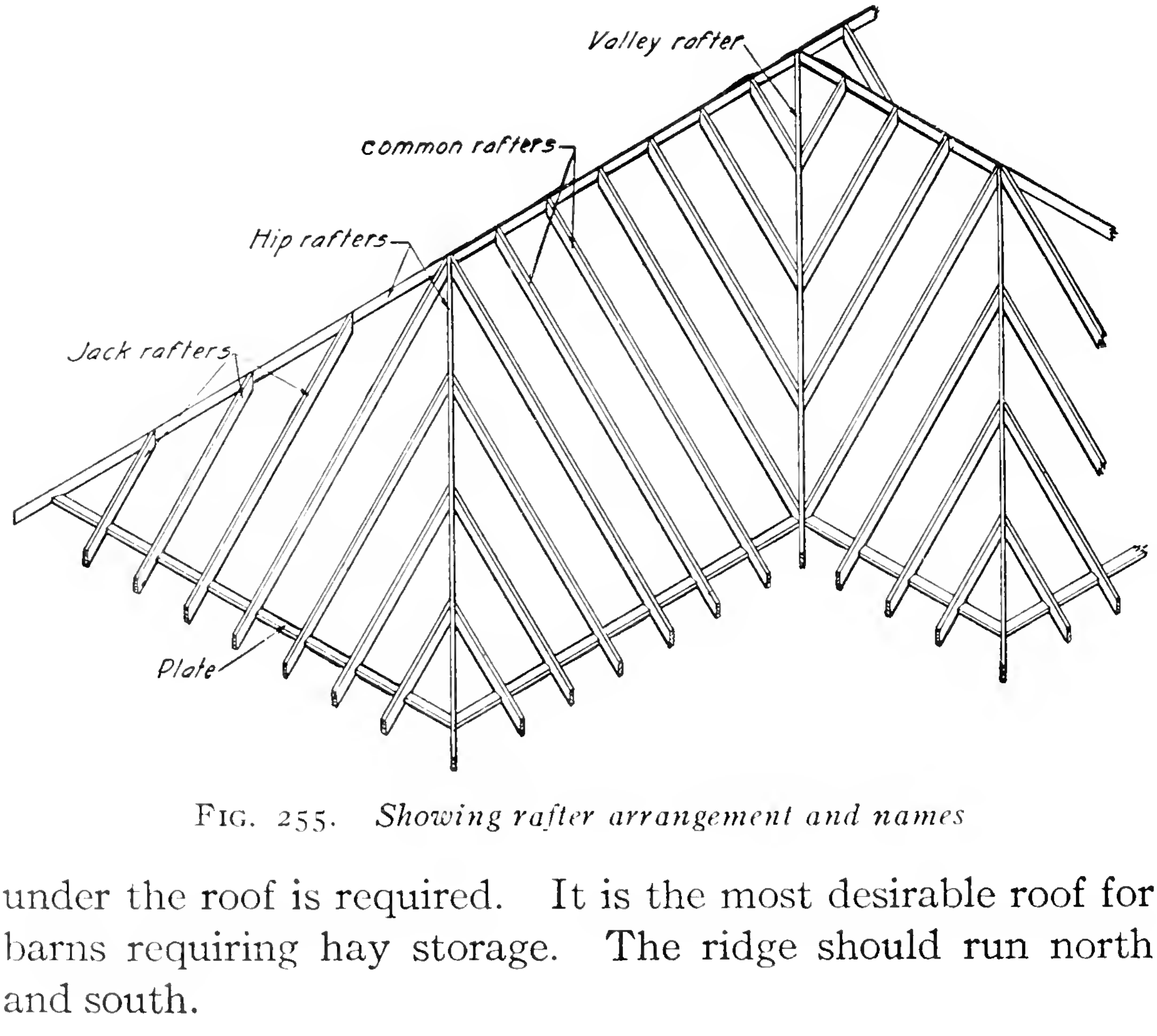

FIG. 255. *Showing rafter arrangement and names*

Half-monitor. The half-monitor roof can be used on buildings up to 24 feet in width which house animals that require maximum light and ventilation. It is in common use for chicken and hog houses.

Full-monitor. The full-monitor roof can be used on buildings of any size that require light and ventilation near the top of the building. The ridge should run north and south.

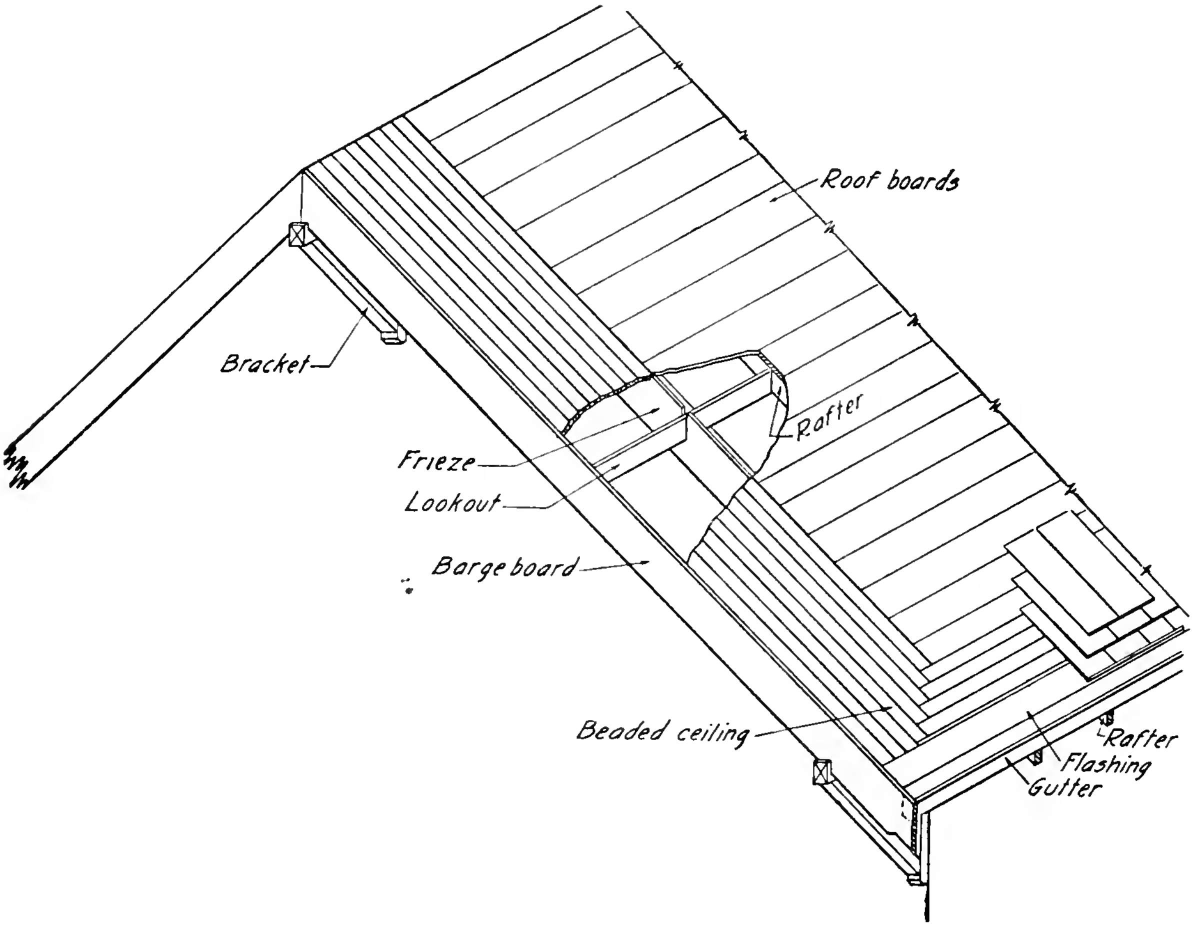

FIG. 256. *Roof projection, using open cornice and brackets*

Hip roof. The hip roof is used on residences and buildings approximately square. Its selection is frequently for ornamental purposes.

Mansard roof. The mansard roof is seldom used on farm buildings. Its selection is ordinarily for ornamental purposes or where an upper story of uniform height is required without waste space above the ceiling. The materials of which the flat part can be constructed are limited as compared with other styles of roofs.

Pitch. The pitch of a roof is an important matter in determining the type of roof covering. The pitch of a roof is designated as the ratio of the perpendicular height of the ridge above the plate to the width of the building. For example, if a building is 24 feet wide and the ridge is 8 feet above the plate, the pitch of the roof, then, is 8/24, or 1/3. Shingles should not be used where the pitch is less than 1/4.

Valleys. In designing roofs, it is highly important to eliminate, as far as possible, all valleys. In the case of heavy snowfalls the valley is a receptacle for much snow. This begins early to melt, run down, and be caught in the heavy depth of snow in the valley, and there frozen. Later meltings cannot get by, and these are backed up the slope of the roof. The final result is the damming of the melting snow until it runs up under the shingles, tile, or slates of the roof, to appear on the ceiling or walls or rooms below in large, permanently discolored areas. Where it is impossible to avoid valleys, much trouble may be avoided by use of an extra-wide valley tin. The ordinary widths are very satisfactory in rainy weather, but are entirely too narrow in regions where heavy snows are encountered.

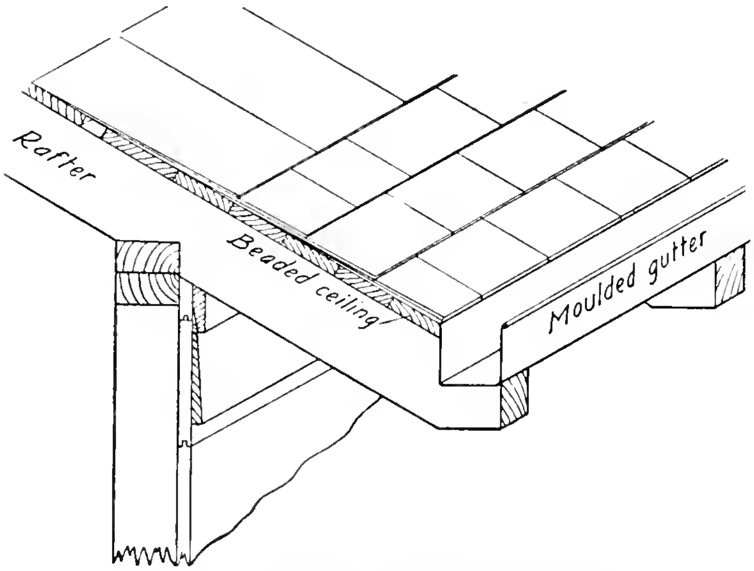

FIG. 257. *Typical open cornice, eave, and gutter (desirable)*

Gutters. It is desirable to hang gutters on all eaves in order that the roof water may be led either to a cistern or to a wasteway, thus preventing a heavy downpour of water in close proximity to foundation walls. The type of gutters which has the least number of shortcomings is the hanging or molded gutter. A box gutter lined with metal at the edge of an inclosed cornice is not so good as the molded gutter, which is hung at the out ends of the rafters or lookouts and not inclosed in any way. If this gutter overflows, there is no chance for the waste to find its way back to the house wall, down inside the sheeting, and eventually to damage the interior finish. The roof gutter is one of the poorest types of gutter that has been used. Downspouts from all gutters should not be smaller than 3 inches, and one spout should not be called upon to take care of more than 20 feet of eave trough.

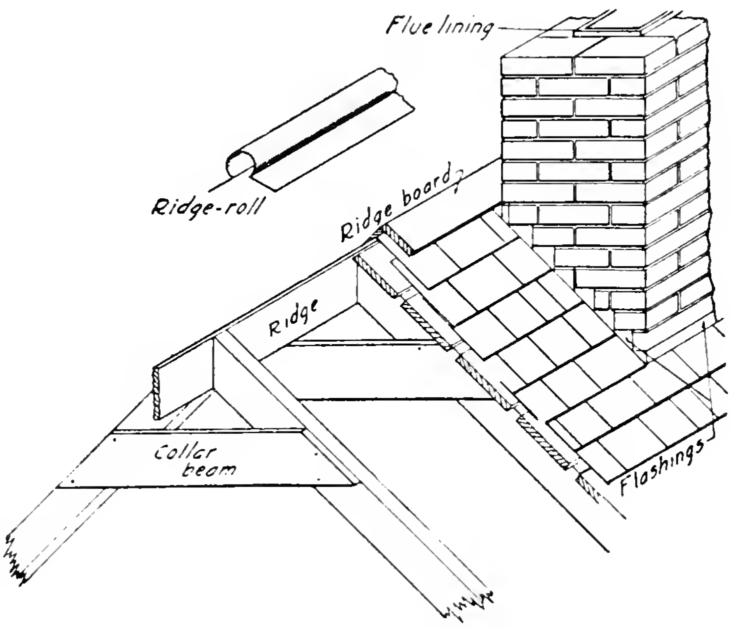

FIG. 258. *Details of roof construction and finish*

Roof coverings. Shingles are packed in bundles of 250 each. They are of varying widths, but have the same covering capacity as 250 shingles 4 inches wide. Four bundles will cover 100 square feet of roof when laid 4 inches to the weather. Dimension shingles are of even widths, 4 inches and 6 inches. They are used when a special-shaped butt is desired.

COVERING CAPACITY OF SHINGLES

EXPOSURE TO WEATHER	NUMBER OF SQUARE FEET OF ROOF COVERED BY 1000 SHINGLES		NUMBER OF SHINGLES REQUIRED FOR 100 SQUARE FEET OF ROOF	
Inches	4 Inches Wide	6 Inches Wide	4 Inches Wide	6 Inches Wide
4	111	167	900	600
4¼	118	177	847	565
4½	125	188	800	534
5	139	208	720	480
5½	153	230	650	437
6	167	250	600	400
7	194	291	514	343
8	222	333	450	300

The application of *rolled roofing* is comparatively easy and rapid. Some manufacturers recommend the laying of their roofing horizontally, others up and down the slope of the roof. If this type of roofing is laid upon a tight, smooth sheeting, thoroughly cemented at the joints, it will last from fifteen to thirty years. It may, in some cases, need painting once or twice during that time. These roofings are made of a felt saturated with asphalt gum. The paint, therefore, should be an asphalt paint. Asphalt is black in color and does not make the most attractive roof. Only the heaviest of the rolled roofings should be used on flat surfaces. Chief among the objections to the rolled roofing is the tendency to buckle with changing temperatures. This may be materially reduced if the roofing is unrolled on a level stretch, thoroughly wet, rerolled tightly, and allowed to stand for several days before being placed upon the roof.

Tar-and-gravel roofing is made on the roof by means of four to eight layers of tarred felt overlapped and laid in hot tar. The surface is then given a heavy coat of tar into which is sprinkled a well-graded smooth gravel of ⅛ to ⅜ inch diameter.

Finishing. *Lath and plaster.* Lath are ¼ inch thick, 1½ inches wide, and 32 and 48 inches in length. Lath should be spaced not more than ⅜ inch apart, though ¼ inch is better, and must be nailed to each studding. Wood lath is sold by the thousand and put up in bundles containing 50 or 100 lath. It requires about 1,500 lath to cover 100 square yards of surface. Plaster board is sometimes used as a substitute for the lathing and the first coat of plaster. The nature of the surface of the commercial plaster board is supposed to be such that a perfect bond may be made with the finish coat. Grounds are necessary for good work where lath and plaster or plaster board and plaster are used. A *ground* is a narrow strip of wood nailed to the studding around door and window openings and at the top of the base-board or wainscoting. The ground makes it possible to finish the wall to a perfect surface and leave it so that casings, baseboards, and moldings may be nailed down tightly to the plaster. Grounds are usually ¾ or ⅞ inch thick. They are 1 inch wide for window and door work, and 4 inches wide for base and wainscoting. Metal lath may be used instead of the wood lath. Metal corner beads are a recent improvement. They make it possible to finish corners so that the cracking of the internal corner is largely eliminated and the damaging of the reëntrant corner avoided by a metal edge.

Plaster work is known as two-coat and three-coat work. The first is the scratch coat. It is intended just to cover the lath. The second is the brown coat. It is leveled and floated to a true surface. The third or finish coat may be either a sand float or a putty coat; the sand float is a rough surface, owing to the admixture of sand with the plaster; the putty coat is perfectly smooth and white, with no sand in it. In two-coat work the scratch and brown coat are run practically together.

QUANTITIES FOR PLASTER WORK FOR 100 SQUARE YARDS

Scratch coat: 350 lb. water-slaked lime and ¾ cu. yd. of screened sand
Sand float finish: 300 lb. water-slaked lime and ¼ cu. yd. screened sand
Using Keene's cement, first coat: 1 part cement, 1 part lime, 3 parts sand
Second coat: 1 part cement, 1 part lime, and 4 parts sand
Finish coat: 6 parts cement and 1 part lime

Patent plaster and Keene's cement are put up in sacks. They are both sold by the ton.

Painting. We shall consider under this head both exterior and interior painting and other finishes for wood and floors.

Exterior painting. All outside surfaces should be primed and painted two coats. The surface should be thoroughly dry and clean. Knots are full of pitch which will discolor the paint if precaution is not taken. This precaution means the application of a thick coat of shellac. The shellac effectually seals the knot surface, and little trouble is experienced with the pitch coming through. A priming coat should be largely raw oil. A little lead and coloring matter may be added, also a small quantity of turpentine. If, however, the surface is dry and the best work is desired, the turpentine should be left out. A week, at least, should elapse before the first coat is applied. This coat should approach the desired color of the final finish. The first coat must be allowed to dry thoroughly before the second is applied. It is a good practice in painting to put on plenty of brush and a thin coat of paint. It is better to wear out several brushes than to apply thick, heavy coats of paint. Thick coats creep and do not dry properly. The result is a rough, imperfectly bonded coat.

Interior painting. There is no marked difference between the treatment of interior and exterior surfaces. The finished job should be a little more neatly and carefully done. This applies especially to the last coat, which should be spread smoothly and evenly. A precaution necessary on interior work is to putty all nail holes after the priming coat has been applied. It is impractical to putty before, because the oil of the putty is quickly extracted by the wood, with the result that the putty shrinks and drops out. If the holes are puttied after the priming coat, the filling material has an opportunity to harden before it loses any of its oil. As white-lead paint turns yellow, interior white paint should be of zinc oxide, or a last coat of zinc paint applied as a protective finish. Enamel paint, as used for interior finish, is a paint in which varnish is used as a vehicle instead of oil. A thorough job of enamel painting calls for four to seven coats, not more than the last two being enamel paint, each coat thoroughly sanded after drying.

Varnishing. Close-grain woods should receive as a first coat a primer of glue or very thin shellac. Open woods should receive a filler of the paste variety. This paste filler is made up of inert material such as fine clay ground or mixed with raw linseed oil and thinned with turpentine to the consistency of thick cream. The paste filler is hard to apply, since an excess must be used in order that all pores may be thoroughly filled. The excess is then wiped off. The surface should dry from twenty-four to forty-eight hours. The final treatment may be shellac and two or three coats of varnish, or three or four coats of varnish without the shellac. Each coat should be rubbed with fine sandpaper or wire wool after becoming thoroughly hard.

COVERING CAPACITY OF PAINT

$$\frac{\text{Area (sq. ft.)}}{18} = \text{lb. white lead in oil (3 coats)}$$

$$\frac{\text{Area (sq. ft.)}}{200} = \text{gal. white lead in paint (or ready mixed) (1 coat)}$$

1 lb. paint will cover	3½ yd.	wood, first coat
1 lb. " " "	5 "	" second coat
1 lb. " " "	3 "	brick, first coat
1 lb. " " "	4 "	" second coat
1 lb. putty (wall and ceiling) will cover	20 yd.	
1 lb. wax " "	125 "	
1 lb. glue sizing (2 gal. water)	100 yd.	
1 gal. mixed paint will cover	35 "	first coat
1 gal. " " " "	20 "	second coat
1 gal. " " " "	25 "	on stonework
1 gal. " " " "	80 "	iron
1 gal. " " " "	40 "	plaster
1 gal. " " " "	125 "	brick, first coat
1 gal. " " " "	300 "	" second coat
1 gal. shellac " "	700 sq. ft.	
1 gal. water stain on wood	750 "	close-grained
1 gal. " " " "	500 "	open-grained
1 gal. spirit "	½ of water stains	
1 gal. oil "	600 sq. ft.	
1 gal. shingle "	½ M	
1 gal. paste filler	300 sq. ft.	
1 gal. liquid "	350 "	
1 gal. enamel	250 "	

Wax floor finishing. In order to give a floor a wax finish it is necessary first to prepare the floor by scraping and sandpapering to a perfect surface, and filling by means of a paste filler or shellac according to the character of the wood. Even when the paste filler is used, it is desirable to apply one coat of the shellac in order to insure a permanent finish. After the shellac has been allowed to set twenty-four hours, it should be rubbed down almost to the wood by the use of wire wool No. 1 or No. 0. It must be understood that shellac is a very poor finish and that all that is on the surface should be removed. The purpose of the shellac is to complete the sealing of the pores of the wood. A spread brush, pad, and weighted brush are necessary for the application of the wax. After the shellac coat has been rubbed, the floor should be dusted off thoroughly and a thin coat of prepared wax applied with a pad. The wax should be allowed to dry or set from twenty minutes to half an hour and then be rubbed with a weighted brush first across the grain of the wood and then with the grain. This coat should be left a day and a second coat applied in the same way. Care should be taken to avoid leaving an excess of wax in corners and around baseboards and base blocks, for such surplus merely acts as a dirt catcher. A third and fourth coat of wax may be applied at any time at intervals of one week thereafter. The upkeep of the floor will require one to three applications of wax per year, depending on the amount of wear. In doorways and hallways it would be well to apply wax possibly once a month in order to maintain the wearing surface and not allow the wood to become exposed and discolored.

Floor cleaning. A very satisfactory floor cleaner may be made of the following ingredients boiled together for ten minutes: turpentine, 1 tablespoon; raw oil, 1 tablespoon; soap, size of an egg; water, 2 quarts. Moisten a cloth with the solution and wash the discolored spots from the floor. This will not cause discoloring on reapplication of floor finish. Where waxed or varnished floors are badly discolored, wire wool dipped in turpentine will very effectually prepare them for refinishing. In cases of bad discoloration a salsoda solution may be used as a reviver, to be followed by sanding, shellacking, rubbing, and varnish or wax.

Refinishing. Refinishing of old paint surfaces involves the removal of part or all of the old coating. Old paint or varnish which shows a tendency to loosen or peel must be removed. On exterior work this means the complete removal of all finish, since it is impossible to apply the new coat over the old where the old has been broken and peeled in spots. The old paint may be removed by burning with a gasoline torch. This process softens the paint, which may be immediately scraped. The burning and scraping should be followed by a stiff wire brush to remove all small loose particles. Interior finish and varnish may be removed in the same way, although it is difficult to remove varnish with a torch without discoloring the wood beneath. It is more satisfactory—though much more expensive—to use a solvent on varnished surfaces. As it is very expensive to remove old varnish, it pays to apply none but the best and in the most approved and workmanlike manner. Good varnish will not crack or peel. When it is desired to revarnish, the old surface may be washed and sanded, then one or two coats applied. On floors it may be necessary to remove the old varnish, but seldom on doors, casings, and other interior woodwork. Such woodwork should, however, be cleaned by means of wire wool dipped in turpentine and wiped dry.

Whitewashing. Whitewash is applied in the same way as paint. Lighthouse whitewash is used hot and the ordinary kinds cold.

Linoleum. A floor covering which may be used in place of finished floors in some parts of the house—especially the kitchen—and certain outbuildings, such as the shop, is linoleum. It is made in thicknesses up to ¼ inch. Its composition is oil and a filling such as ground cork or waste linen fiber. The better grades of linoleum are known as inlaid. In these the color extends through the whole thickness and is not merely painted on the surface. Linoleum is made of a layer of burlap on which is pressed the desired thickness of the compound. It wears out from beneath about as fast as from above on account of water which finds its way to the burlap underlay. It is essential, therefore, when linoleum is laid, that the edges be made tight and cemented down, in order that no moisture may get under the surface. The laying of linoleum requires considerable time. It should first be unrolled on a flat surface and allowed to flatten out. As it will creep for several days, it is impossible to unroll and fit linoleum the same day. If this is attempted, there will be shrinkages and bucklings. If a floor covering of low cost is desired, where appearance and color of finish are not an object, a heavy grade of rolled roofing may be used. This should be treated the same as the linoleum with reference to creeping and buckling.

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CHAPTER XVI

FARM BUILDINGS

FACTORS INFLUENCING LOCATION, ARRANGEMENT, AND STYLE OF BUILDINGS

In the determination of the location and arrangement of farm buildings several factors must be considered. Sanitation, expense, conservation of time, and distance from markets all govern to a certain degree. In the early settlement of the country natural water supply, timber, or proximity to a road or trail frequently was the controlling influence. Pioneer buildings, constructed of such materials as were available, were erected and added to from time to time, and fields laid out in conformity to conditions as they then existed. While later developments such as new roads, deep wells, or the exhaustion of the lumber supply may have deprived the old site of its superiority, it is seldom that a complete reorganization is possible. Generally the development of the farmstead has extended over a long period of years, new improvements being built as the need occurred, and to remove them all at one time would involve a prohibitive expense and waste of material.

The location and arrangement of the buildings depend to a large extent on personal preference and individual conditions. The ideal site would be one located on high land where there is a sandy or gravelly subsoil. Flat or black soils are likely to be damp and cold, making it difficult to secure proper drainage. For convenience in reaching all fields with stock for pasturage or for work, the center would be the best location, but to reduce the distance from neighbors, markets, and rural mail deliveries, a point on the public road is desirable. High dry ground on a public road and near the center of the long side of the farm would be a happy compromise.

The highest land should be selected for the house, which should front the road at a distance of from 100 to 150 feet. The yard may be a half-acre to an acre in extent, and the garden and orchard from a half-acre to two acres, according to the suitability of the locality to the growing of fruit and vegetables. Many fruit trees are well adapted to use in the yard as shade trees.

The barn site should be a little lower than the house and in a direction other than that from which the prevailing winds blow. Such an arrangement will prevent water from draining toward the house and minimize the odors carried by the winds. Usually 125 feet between house and barn is sufficient. The hog house should be somewhat farther away; cribs and granaries should be between barn and hog house for convenience in feeding; and other buildings should be arranged so as to reduce the travel necessary to reach them. A garage, particularly when used for the storage of gasoline and oils, should be removed some little distance from the other farm buildings.

While separate buildings may be used with profit, it is often advisable to consolidate some of the smaller ones. Wood, coal, and cob storage and an outside toilet can usually be provided in an end or corner of another building such as the machine shed. Garage and shop make a good combination.

Styles of buildings, roofs, roof coverings, sidings, and floors have already been discussed in the chapters on building materials and building construction. These will vary largely with the locality, the nature of the farming operations, and the individual ideas of the owner. Each building added should be consistent with the other permanent buildings on the place and in line with those on adjoining farms. Temperature, leading farm products, and availability and cost of materials determine to a considerable extent the class of buildings constructed. Buildings economical and suitable for an Illinois corn farm might be neither on a Red River Valley wheat farm.

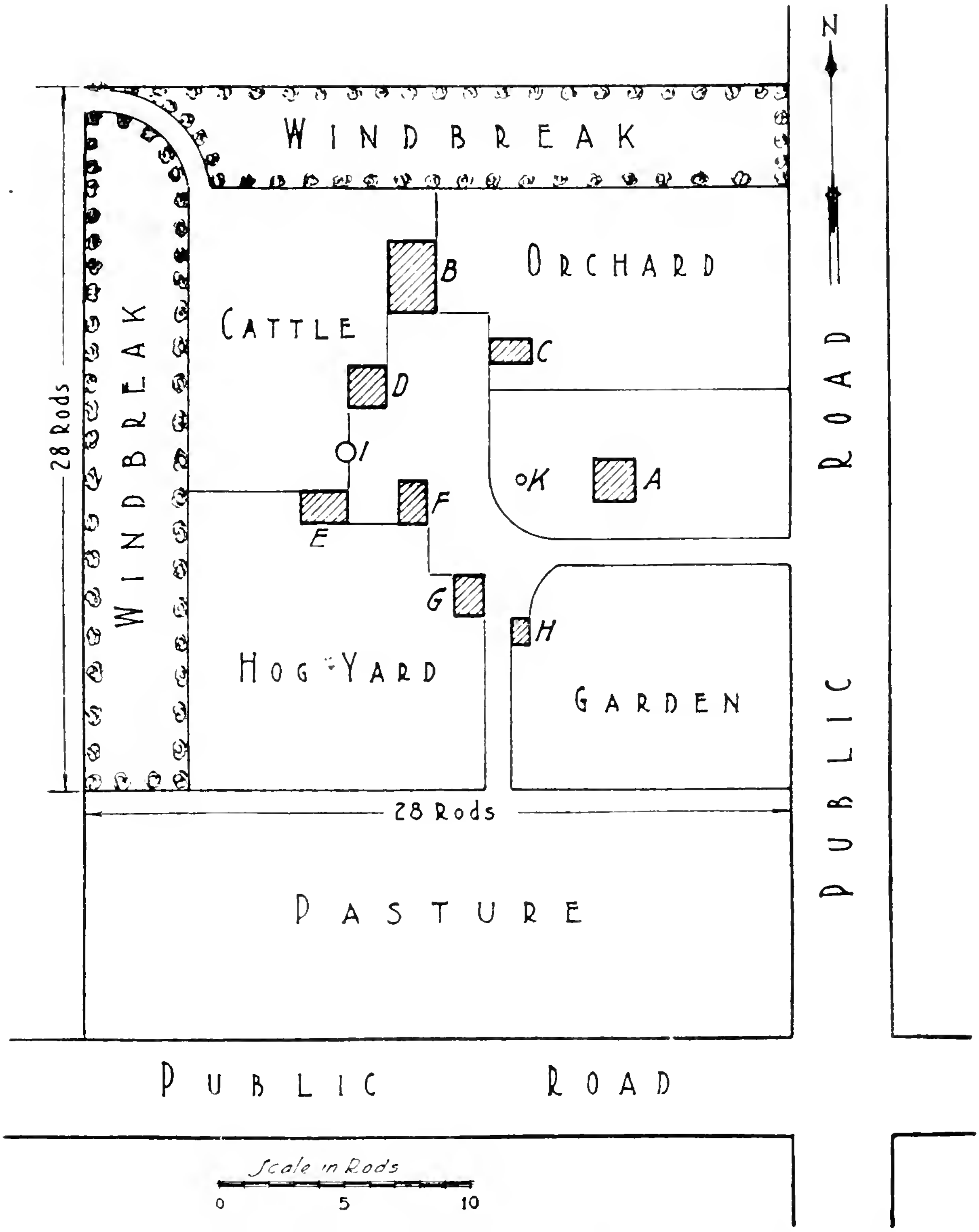


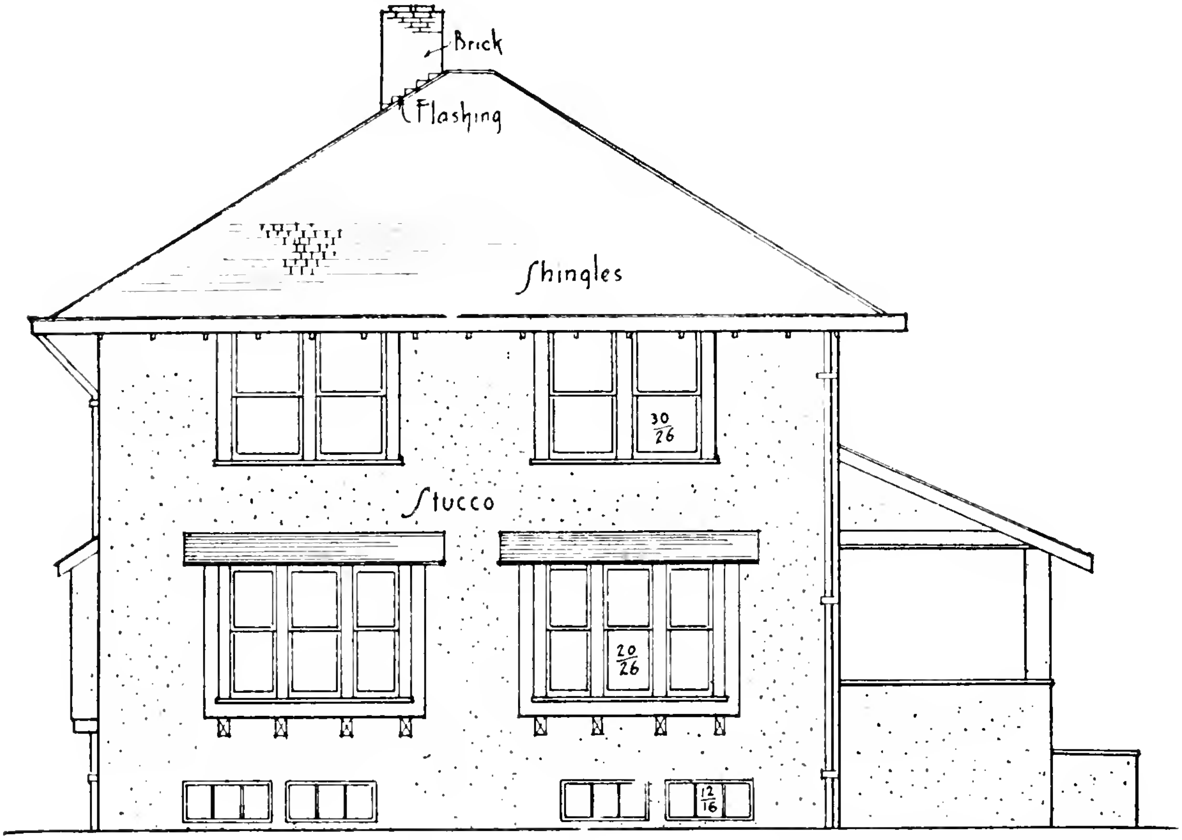
FIG. 259. *Suggested plan of farmstead covering 5¼ acres, including road*

A—Dwelling, 30′ × 30′	*F*—Double crib, 24′ × 36′
B—Barn, 34′ × 48′	*G*—Machine shed, 20′ × 32′
C—Chicken house, 16′ × 30′	*H*—Garage, 12′ × 16′
D—Granary, 24′ × 32′	*I*—Water trough
E—Hog house, 24′ × 32′	*K*—Well

On the prairies of the Northwest a strip of land 2 to 4 rods in width on the north and west sides of the farmstead should be planted with trees for protection against winter winds and the drifting of snow around buildings.

HOUSE

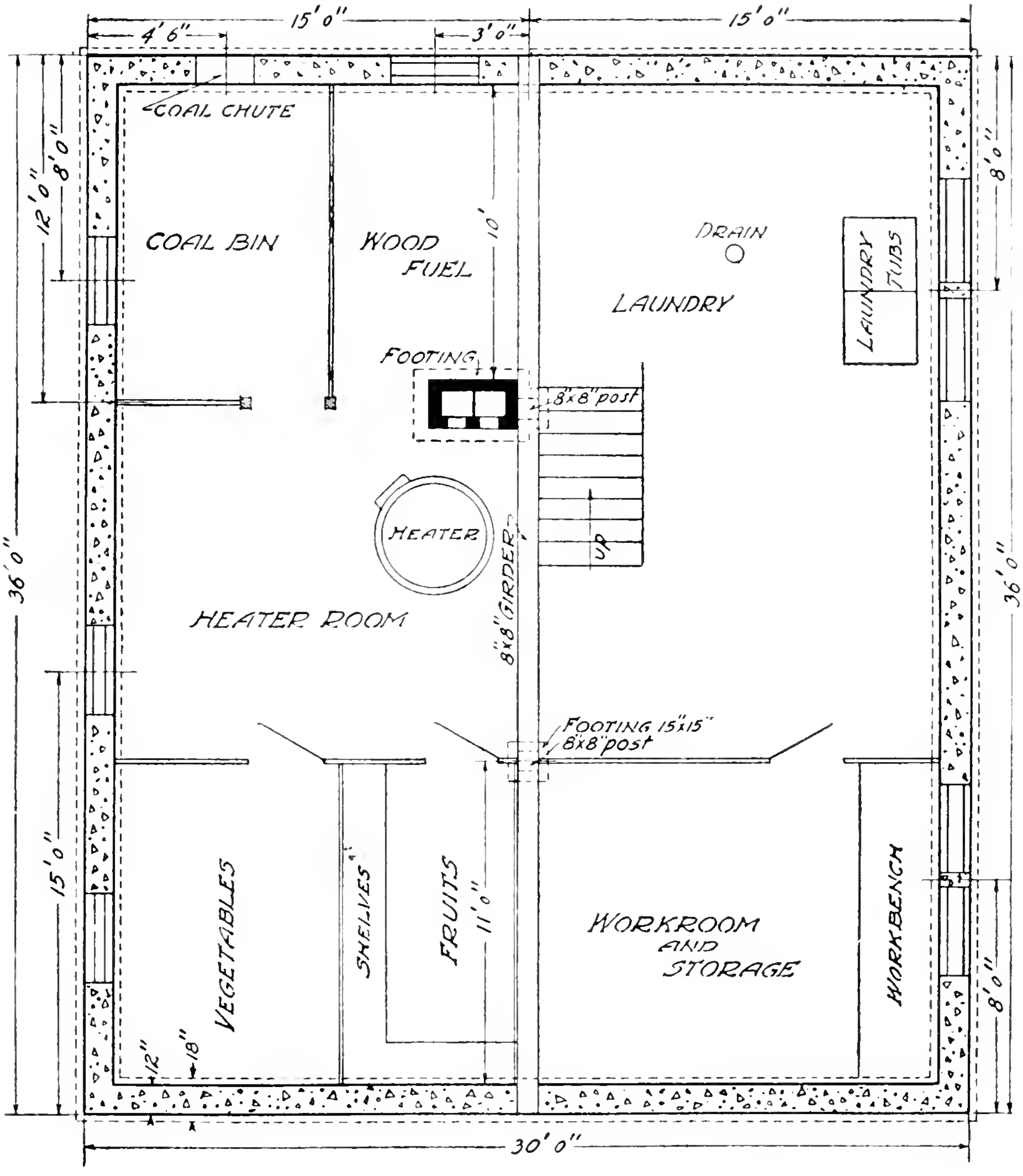
The rural house is as much a part of the farm equipment as is the barn or machinery list. (See Figs. 261–263 for desirable interior plan.)



After University of Minnesota

FIG. 260. *Exterior showing use of window grouping and roof projection*

Exterior. The size of a house is determined largely by the individual taste of the owner, the number of persons it is to accommodate, and the cost of construction. The appearance from the outside has a very large bearing upon the attractiveness of the whole farm site. It is, however, unreasonable to suppose that rural communities can afford to have competent architects furnish plans for their buildings. If this could be done, pure types, such as Colonial or Mission, might be secured. A few of the features upon which stress may be laid will aid materially in securing a



After University of Minnesota

FIG. 261. *Basement plan of seven-room house, square type*

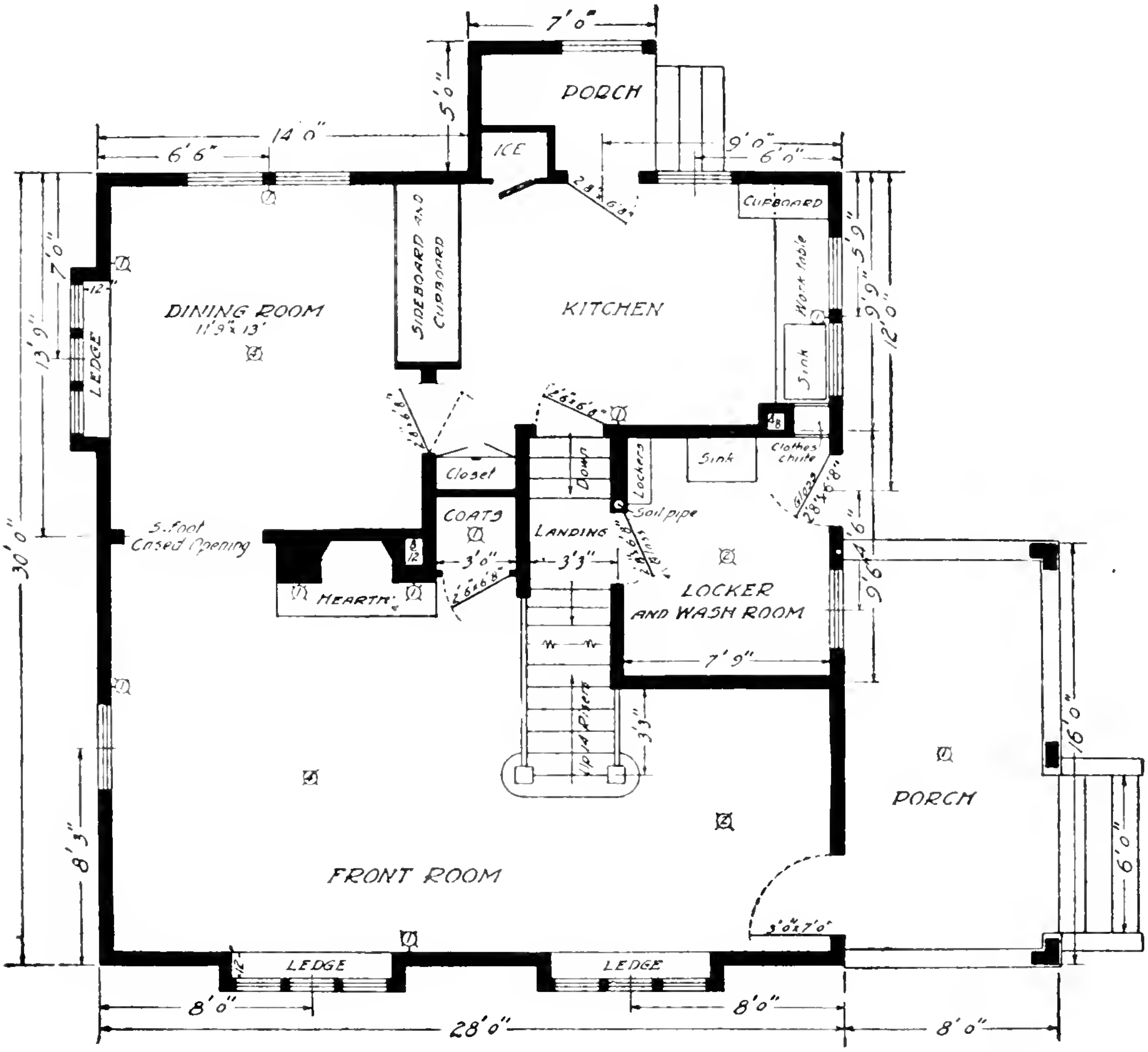
pleasing external appearance and will in many cases increase the attractiveness of the interior.

Plain, simple treatment of the exterior has one feature to recommend it—initial cost. As a means of developing a little variation the following suggestions are made. The plain beveled siding may be broken up by bands at the second-floor line and at the top of windows. This may be further developed by the use of shingles or stucco above the first floor, or of brick or stucco on the first story and shingles above. The so-called half-timbered effect of stucco, as well as shingles, is not to be recommended, as this furnishes opportunity for driving rain to find its way through to the interior wall surface. The architectural features above mentioned will add very little to the original cost of the house and will afford daily satisfaction and seldom fail to return their added original cost when a sale of the property is made.

The roof should not be too steep. If valleys are eliminated, a one-fourth to one-third pitch will be found altogether satisfactory. The roof projection can be made large —30 or 36 inches, instead of the usual 18 or 20. It is poor building policy to install windows of a tall, narrow variety. It has been the practice to cover the upper half of the window with a window shade. This effectively eliminates the light from the upper half of the window. Economy of glass surface may be accomplished by wide, low windows placed in multiple or triple, large panes of glass thus being eliminated. The effect of this feature on the appearance of the house is really surprising.

A front porch has always been considered a feature of importance to a dwelling. It should be located where it will furnish the greatest degree of comfort to the occupants. As the latter part of the day is practically the only time when the average householder can occupy his porch, one on the south and west sides is of little value. It should appear on the east or north and east sides. A kitchen porch, screened in summer and glassed in winter, is a great convenience. It is an ideal place for the refrigerator and prevents the entrance of flies. In winter it acts as a direct shelter and also diminishes the loss of heat occasioned by the opening of the kitchen door. It also catches a considerable quantity of the mud and snow that would otherwise be tracked into the kitchen, and it may have a place provided for working clothes.

Kitchen. The kitchen is the most important room in the house. Features which will differentiate this room from the city dwelling are larger size, more cupboard room, and closer connection with a dining room. Sanction can hardly be given the present practice of building a kitchen which is too large. Some such kitchens have been noted as large as 12×16 feet and 14×18 feet. If the kitchen is also used as a dining room, this size is not so extravagant, but it is out of proportion when a separate room is provided and used for the dining table. The kitchen should be provided with plenty of light and a work table in front of the windows. Considering the importance of this room, it should not be placed in the most undesirable corner of the house. It is to be occupied more hours than any other room and should



After University of Minnesota

FIG. 262. *First-floor plan*

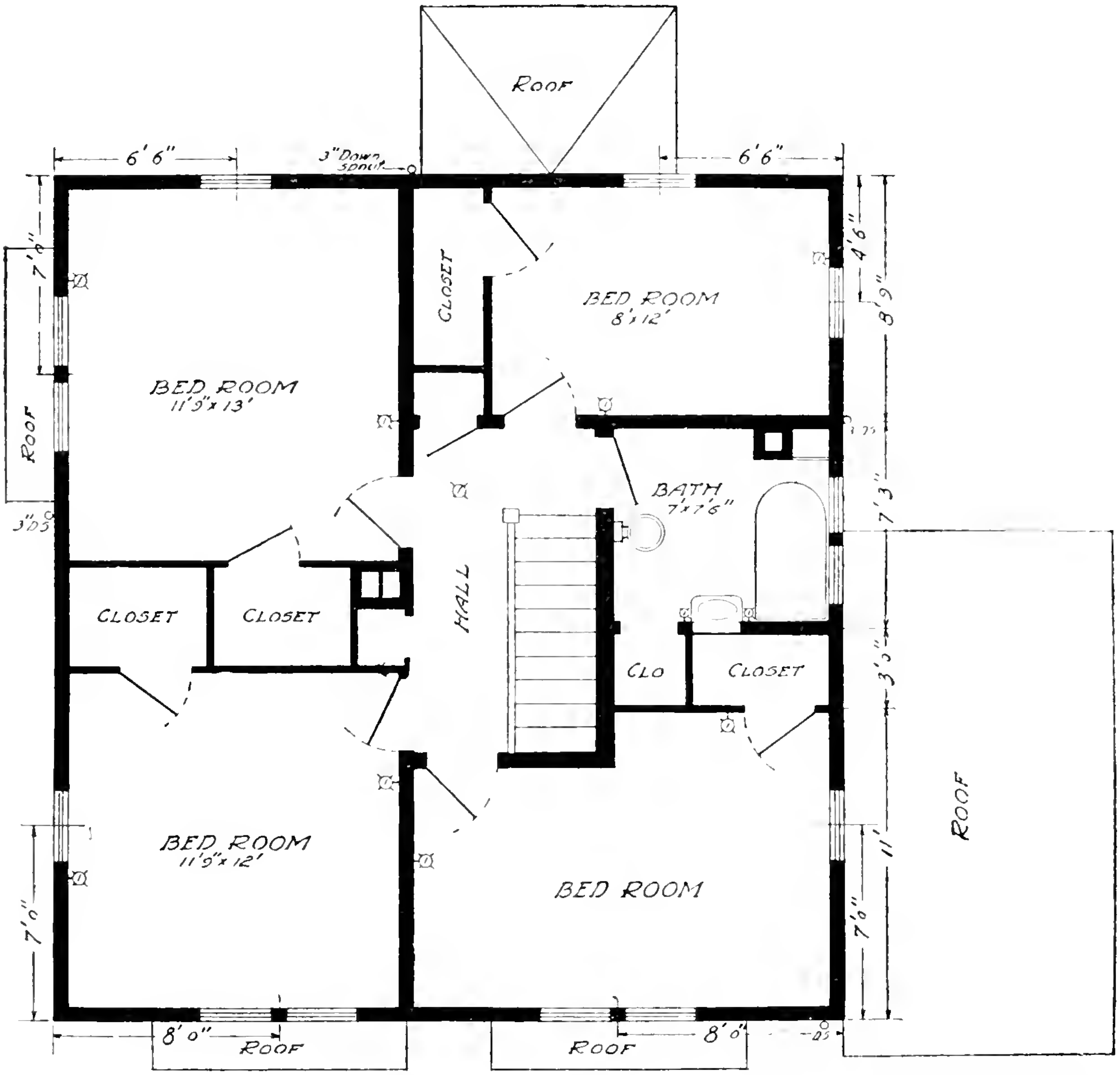
be placed where sunlight is abundant and the outlook is most pleasant.

The shape of the kitchen must depend to some extent upon the possible location of doors. Three doors are the least that should be found in a kitchen—an outside door, a cellar door, and one leading to the dining room. The use of the kitchen wall space for cupboards and cabinets eliminates the necessity for a pantry and places the shelf and storage room where it may be reached with fewer steps.

A sink is a desirable part of the kitchen equipment, though found at present in few rural homes. It requires the presence of a flowing water supply. Regular sink installments are made about 30 inches from the floor. That is the height of the ordinary table. It is contended that this is too low. The sink can as well be placed higher by 4 or 6 inches. This means, however, that the work table will be rather high if placed flush with the top of the sink. The work table can be covered with zinc or have a porcelain top. The expense is not excessive and a table surface is provided which is easily kept clean.

Dining room. A dining room should be well lighted and a more pleasant room than is usually chosen. This room must be occupied every day, whether bright or gloomy outside. It is more reasonable to make this an attractive room than to save the choice location for a living room which may not be occupied more than a few hours each week, and most of those during the evening when artificial lighting will be depended on for a large part of the cheer and attractiveness. The average dining table is 4½ feet wide. This means that 11 feet should be the minimum width allowed for a dining room. The length necessary will depend upon the size of the family to be accommodated.

Living room. It is a mistake to place a porch where all living-room windows will be shaded by the porch roof. It is usually necessary to utilize about half of one side of the house for entry and stairway. This side is the logical one for the porch. All rooms should contain as many windows as possible. These not only are features of external appearance, but will always add to interior attractiveness. A fireplace adds greatly to the beauty of a living room and, whether furnace or stove is used, it need not interfere with the heating system. Besides making the room comfortable on damp chilly days in spring and fall, it serves as a powerful ventilating agent.



After University of Minnesota

FIG. 263. *Second-floor plan*

Bedrooms. One of the essential features of a bedroom plan is room for a double bed. Too often a house is completed and it is found that there is no room for a bed to stand where it will not be directly in front of a window. A room 11 by 11 feet is about as small as a bedroom can be built and allow space for necessary furniture and the doors to swing clear. Each bedroom should have at least two windows. Closets are essential. They will be found more easily aired and convenient if no doors are hung. A light curtain is all that is necessary to close off a closet.

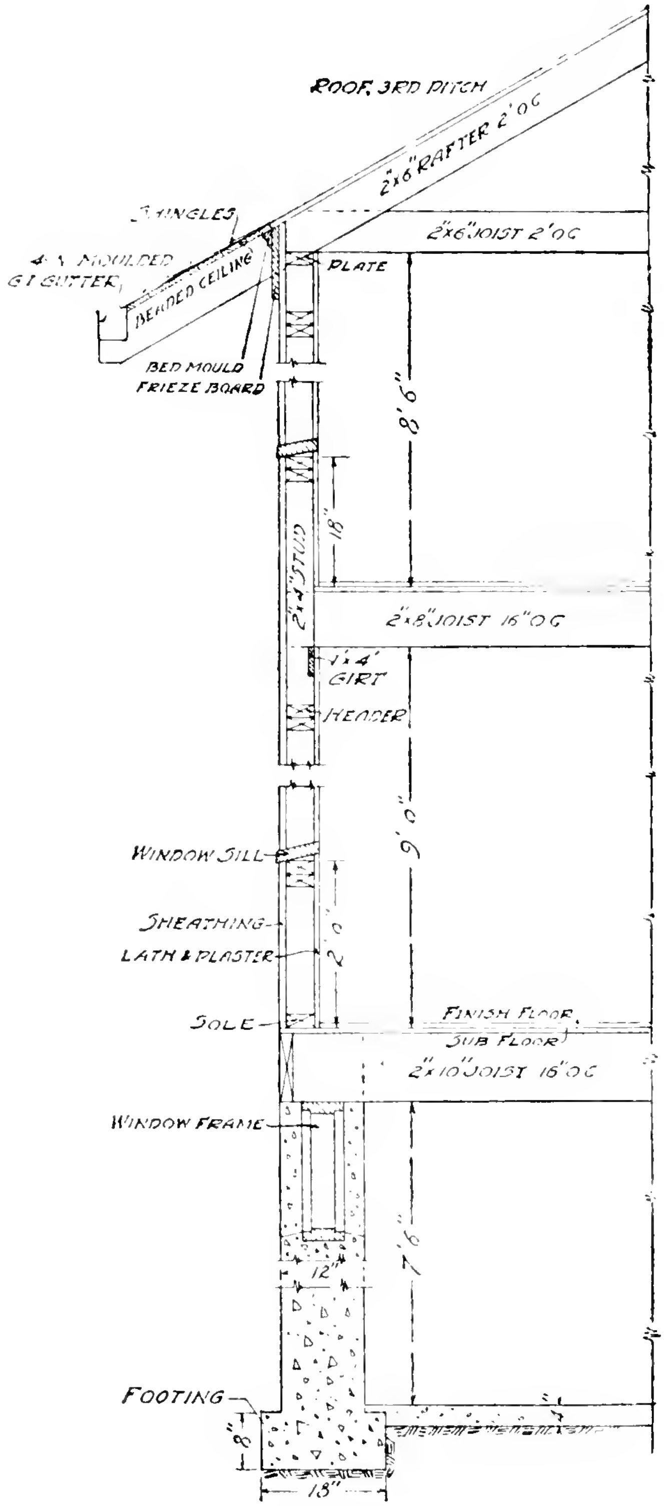


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FIG. 264. *Section showing exterior wall construction*

Sanitary system. Under this heading will be considered the bathroom, laundry, and men's washroom.

Bathroom. A bathroom is as much of convenience in the rural house as in the city dwelling. The bathroom equipment is mentioned in connection with the water supply. A bathroom need not be large—6 × 8 or 8 × 8 feet. A clothes chute from the bathroom to a laundry room below is a convenience, but a source of much trouble as regularly installed. Extra partition space must be provided if this chute is to clear itself at all times. The space between studdings and plaster is too narrow and it often clogs.

Laundry. The location of the laundry is open to much difference of opinion. The basement, or cellar, is the most convenient place, in some ways, for the place is already provided and the soiled clothes will find their way to this room through chutes. The first-floor laundry is probably the most popular, because it is not so radical a departure from the old practice of utilizing the kitchen during wash day. The basement laundry necessitates an auxiliary provision for heating water. It also often makes the disposal of waste water more of a problem than any other location. A laundry room in connection with a milk house where a heater is already installed makes a very convenient solution of the laundry problem. Power for washing purposes may be taken from a small gas engine or storage battery or from an outside source of electric current.

Men's washroom. Another feature which characterizes the rural residence is the necessity for a convenient place in which the workmen may hang their work clothes and a place where they can wash without encroaching upon the time and equipment of the kitchen. This room may be incorporated with a laundry room on the first floor, or in conjunction with a grade entrance to the cellar, which would place it a little below the level of the house proper.

The washroom and the laundry must be warm and light. If not well heated they will not be used for the purpose intended, and if not well lighted they are difficult to keep clean and sanitary.

Hallways and stairs. While it is well to eliminate waste space, hallways and stairs should be made sufficiently wide to permit the moving of large pieces of furniture. Taking a heavy or bulky piece in and out of an upstairs window is a decided inconvenience. Light is also essential, especially at the head and foot of the stairs to prevent accidents. The cellar stairs may have the bottom and top step painted white as an additional precaution.

Basement or cellar. The drainage and material for the construction of the basement are discussed elsewhere. Frequently but one room is built, but it is more convenient if this is partitioned off into smaller rooms. If a furnace and coal bins are included, the partitions should have battened cracks and be ceiled overhead to prevent the penetration of coal dust and fine ashes.

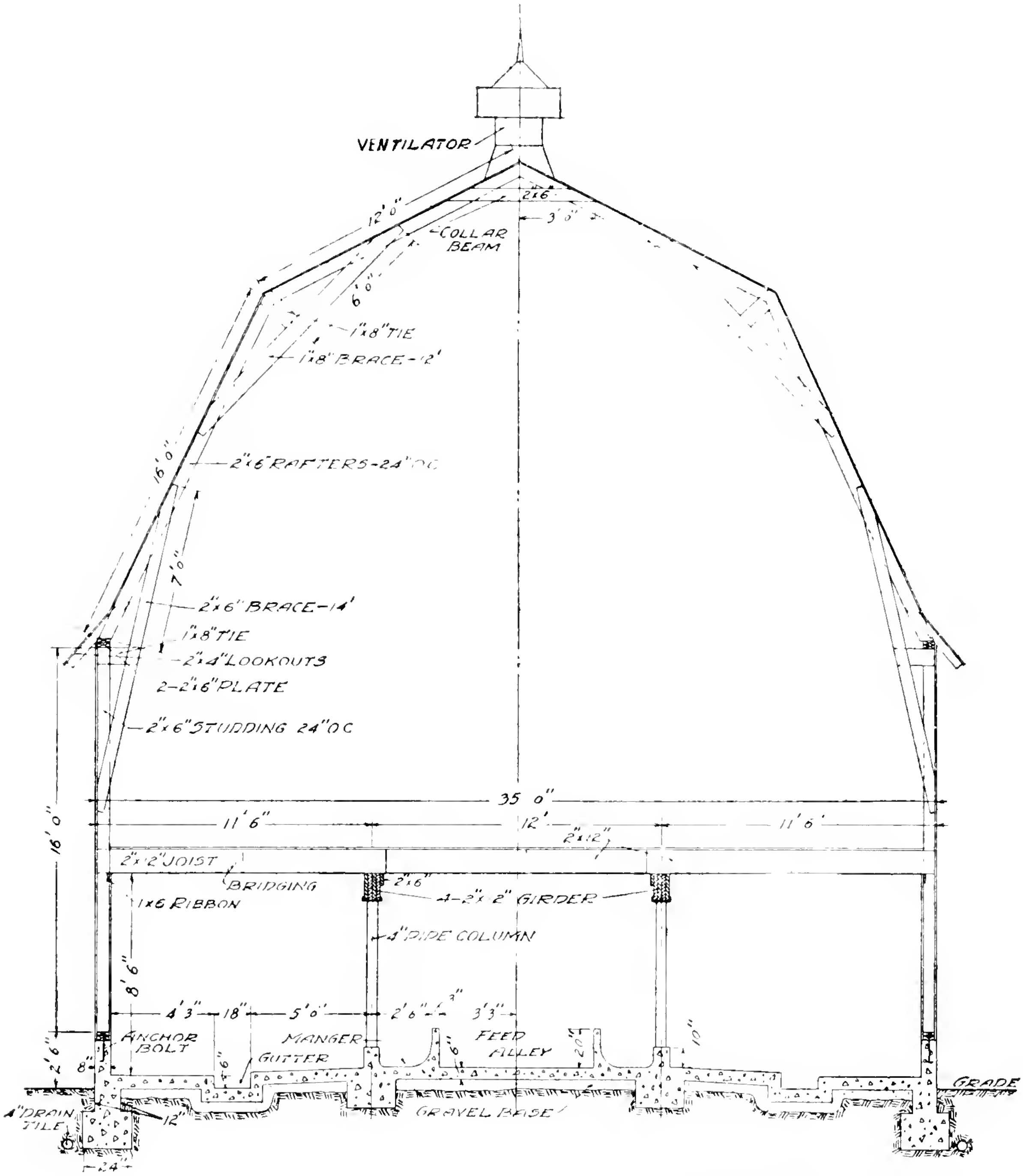

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FIG. 265. *Balloon-frame barn section*

BARNS

Frame. Barns may be classified according to the type of framing used in their construction as timber and plank. The plank frame barn with plank trusses is recommended, or that without the trusses, known as the balloon frame (Fig. 265.) The timber frame is not so popular as it was at one time. The plank trusses and balloon frame both lend themselves to the use of lighter-dimension lumber, provide more open haymow space, and usually cost less than the timber frame.

Use. Barns may also be classified according to their use, as horse, dairy, general-purpose, feed, and sale. Any of these barns may be constructed in the simple rectangular shape, **L**-shaped, **T**-shaped, **H**-shaped, with or without side sheds, six- or eight-sided, or round. The limit of the width of a barn is two rows of stalls, together with feeding and cleaning alleys. This width is about 34 feet. Added

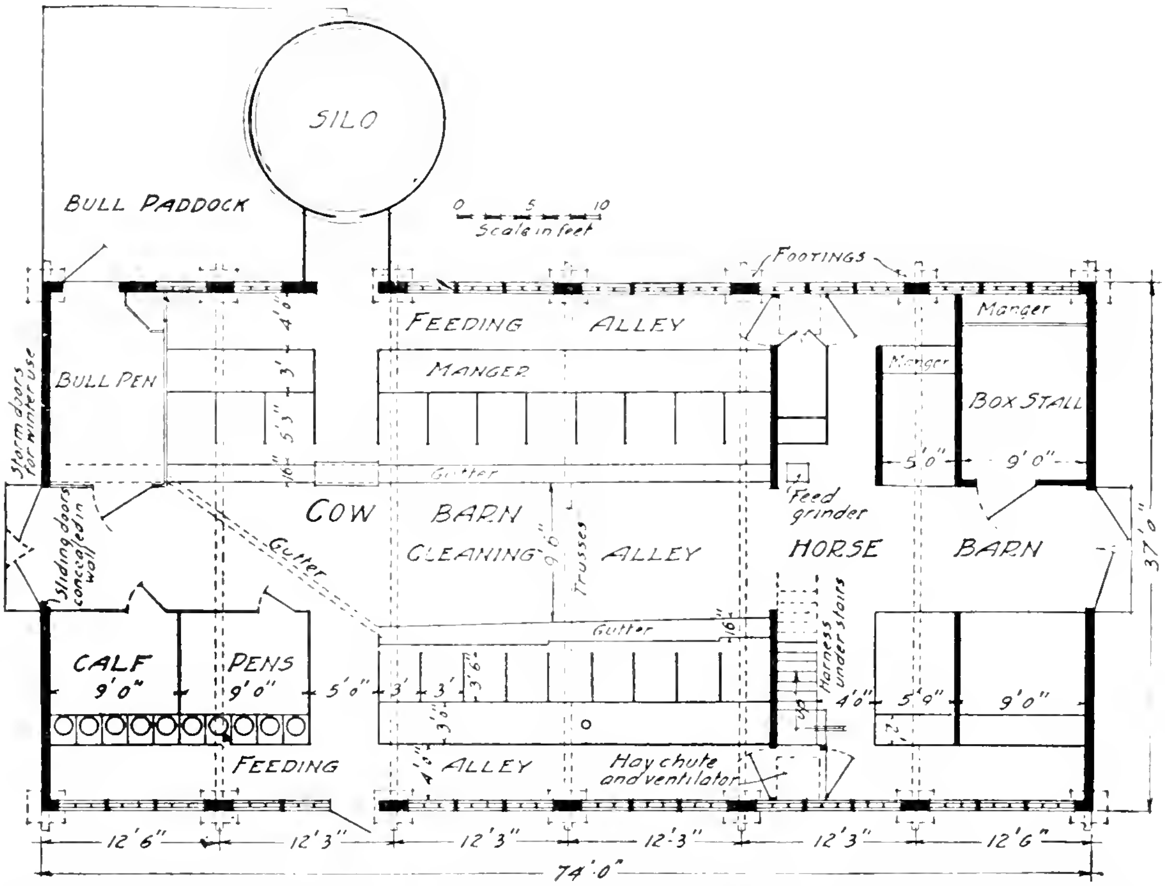

FIG. 266. *Floor plan of a general-purpose barn. When used in a dome or arch-roofed barn and no posts are used in the stall room, the load is carried on trusses indicated by dotted lines*

room is obtained by development of the **L**, **T**, and **H** shapes. A horse barn must necessarily be a little wider than a dairy barn. A general-purpose barn need not be much wider than a dairy barn. A feed and sale barn for either horses or cows is usually 4 to 8 feet wider than a farm barn, the extra width providing for the convenience of purchasers in viewing the stock offered for sale. The round, six- and eight-sided barns are limited to 36 feet in diameter when no silo is built in the center, and to 50 feet with the silo. Diameters greater than this leave in the center of the barn too large an area which is dark and undesirable stable space.

The general-purpose barn usually provides for all kinds of stock, together with hay and grain for feeding. It is a big unit, but makes winter feeding much more convenient than when the feed is stored in separate buildings at some distance. One ton of hay occupies about 512 cubic feet loose and about 25 cubic feet baled. Straw occupies about 650 cubic feet per ton loose.

Barn ventilation. The motive power of air currents in barn ventilation is limited and uncertain, and it is necessary in the planning and installation of a ventilating system that unfavorable conditions be provided for. Such a measure is the choking of oversized inlets and outlets by means of dampers when the weather is cold and the wind high. Inlets need not be so large as outlets, since there is a large percentage of leakage around windows and doors and through walls. Dairy barns built with double insulated walls and storm windows will be found to require a greater circulation of air to remove the moisture than is actually necessary to secure the required degree of air purity for breathing. This moisture comes from two sources: from the body of the animal and from the water used for flushing concrete gutters and that in mangers for drinking purposes. If too much air is admitted in cold climates, the inside temperature becomes too low. The desirable temperature has not been definitely determined, although it is usually agreed that it should not be below 50° Fahrenheit.

There are two systems of barn ventilation in use, the King and the Rutherford, the main difference being in the shape and location of the intakes, as indicated in the illustrations. In the Rutherford system the air is admitted at the floor, across which it moves to the outlet located at the same elevation and is carried by a shaft to the highest part of the building (Fig. 267). In the King system the air enters a shaft near the floor and is carried up to the height of the ceiling, where it is admitted. In this method the cold air becomes tempered by the heat before reaching the animals and does not constitute a cold draught. The outlet is located near the floor, the shaft ascending to the highest part of the building (Fig. 268).

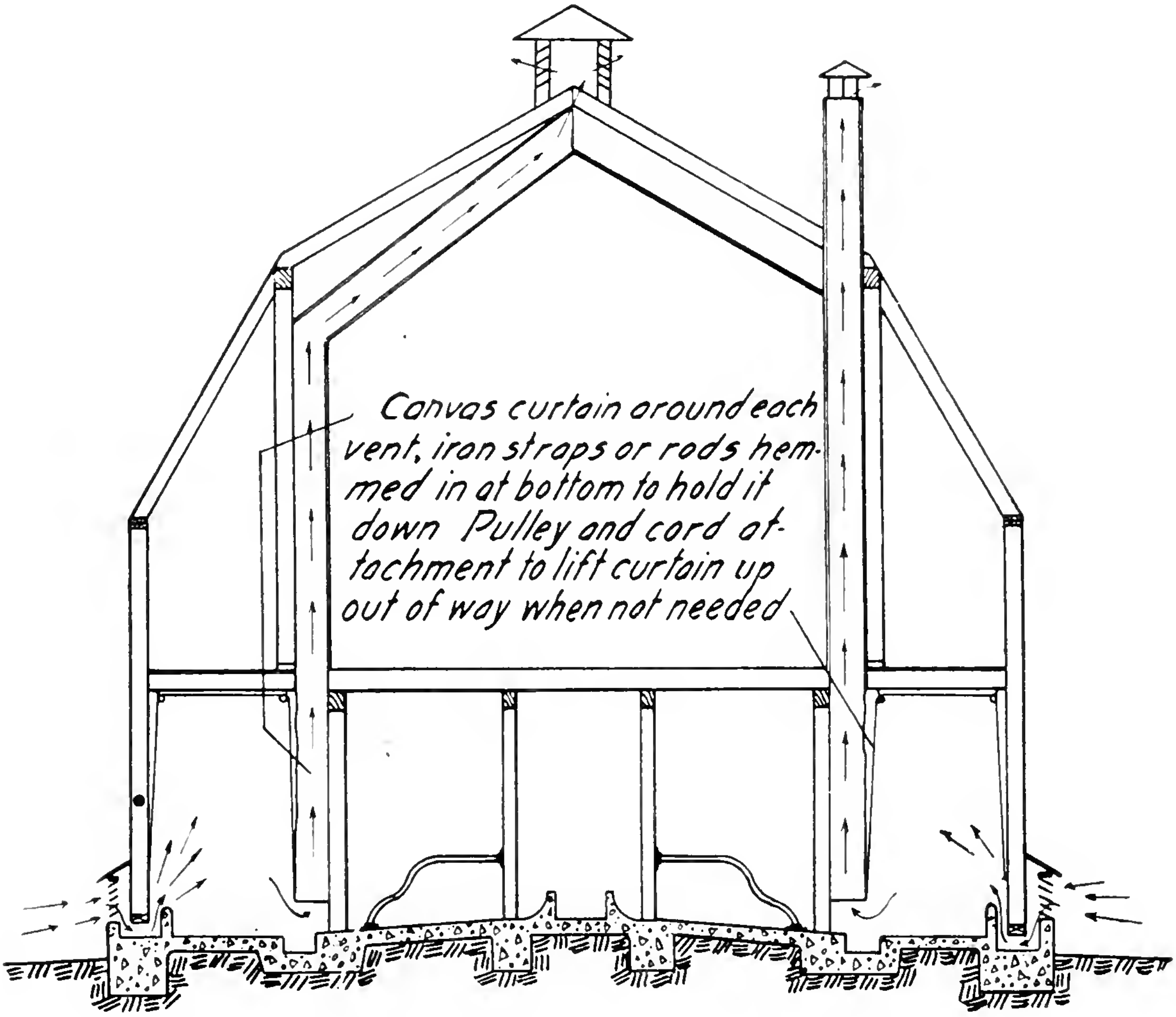

FIG. 267. *Rutherford system of barn ventilation*

The table below, after L. J. Smith, *Bulletin 13*, Manitoba Agricultural College, gives the approximate cross section per animal of outlet flues of various heights in the King system.

AREA OF OUTLET FLUES PER ANIMAL

Height of Flue	40 Ft.	30 Ft.	20 Ft.
Horse	36 sq. in.	40 sq. in.	44 sq. in.
Cow	30	34	38
Hog	12	14	16
Sheep	8	9	10

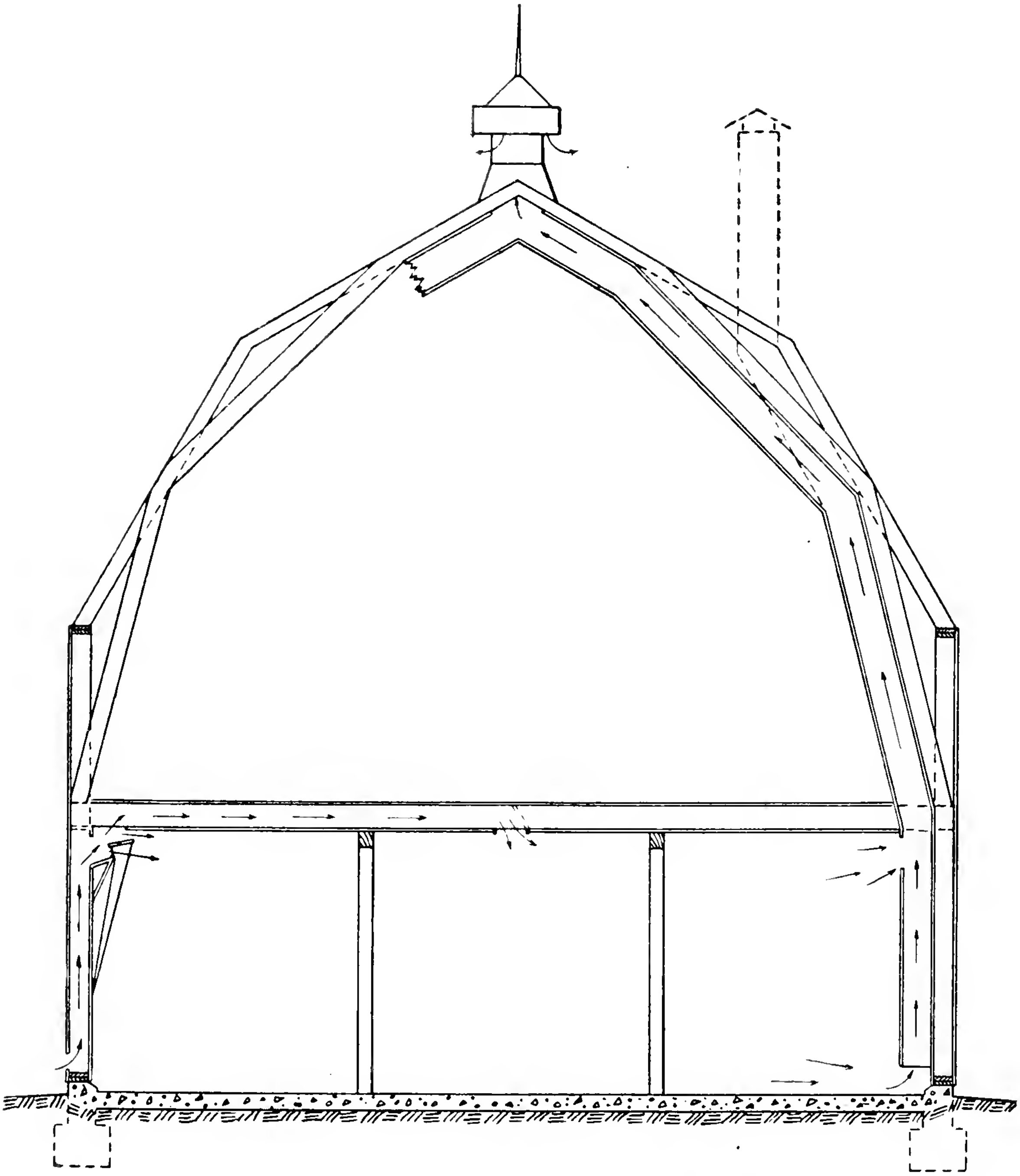

FIG. 268. *King system of barn ventilation*

It has been found that the minimum circulation of air occurs when the temperature is 15° or 20° above zero on the Fahrenheit scale. A more rapid circulation occurs when the temperature is either greater or less. As the above table is computed for this temperature, it should be ample under all conditions.

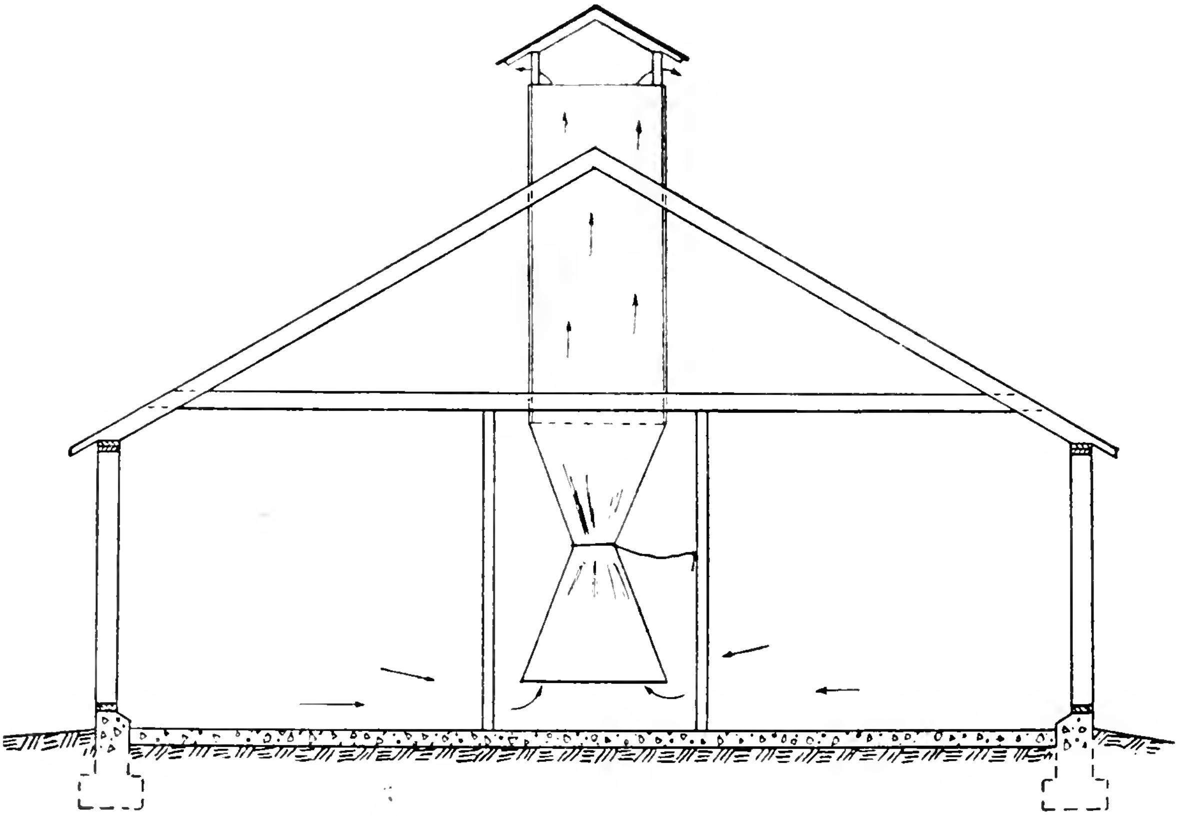

FIG. 269. *An ideal system for ventilating a one-story barn*

HOG HOUSE

Construction. The essentials of hog-house construction are a floor easily kept clean and dry, plenty of direct sunlight, and ventilation to remove the excessive moisture which arises from damp floors and feeding troughs. The expense per pen of a hog house must usually be less than $30 unless more than one litter a year is dropped. The type of roof most common is probably a broken monitor for two rows of pens and a shed roof for one row of pens. The hog-house floor is the one detail upon which there is little common opinion. Concrete is the most desirable except that it is considered by some cold, a disadvantage which may be overcome by the use of an abundance of bedding or a wood deck over the bed portion. Common wood floors in a permanent hog house are not at all satisfactory, being hard to clean and keep dry unless held up off the ground. When this is done, a harbor for rats is provided.

The pens should be 6×8 to 8×8 feet. There should be a guard rail around that part which is to be used as a bed. Otherwise the small pigs may be squeezed to death. This rail should be 8 inches above the floor and 8 inches from the wall and be made of 2×4 lumber or gas pipe of the same diameter as the pipe partitions. The rail should be supported horizontally from the partition and not vertically from the floor.

The feeding alley may be 5 to 8 feet in width, 6 feet being recommended by several authorities. Feed bins should be provided convenient to the feeding alley. In the cold sections it is usually found necessary to provide some heat when pigs are to be dropped early. This is not so extravagant an idea when the feeding of warmed or partially cooked

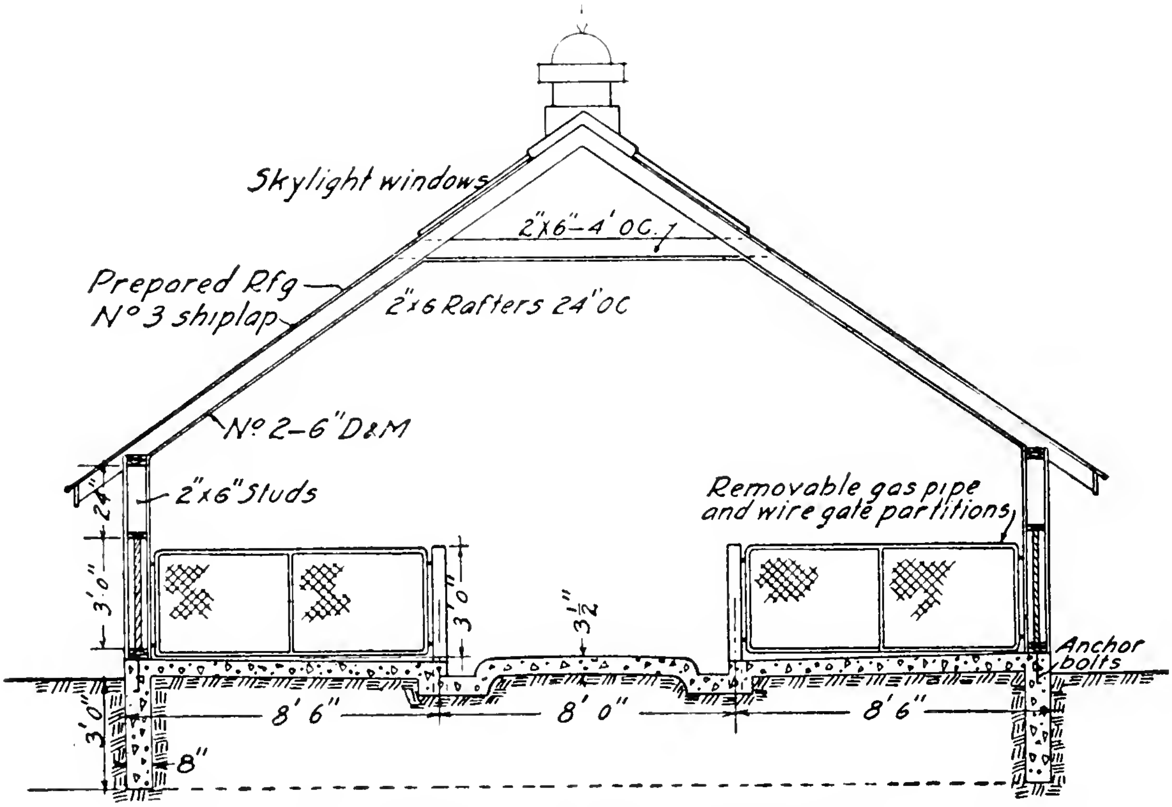

FIG. 270. *Cross section of hog house with skylights. This roof should run north and south.*

feed is appreciated. All pens should receive direct sunlight for a part of the day (Fig. 271).

The cot or colony house may often be used as a substitute for the large regular hog house. Its construction must be quite simple. It has the advantage of being light, which enables the moving to a more dry and desirable spot for young pigs. The floor should be practically the same size as a pen in the larger hog house.

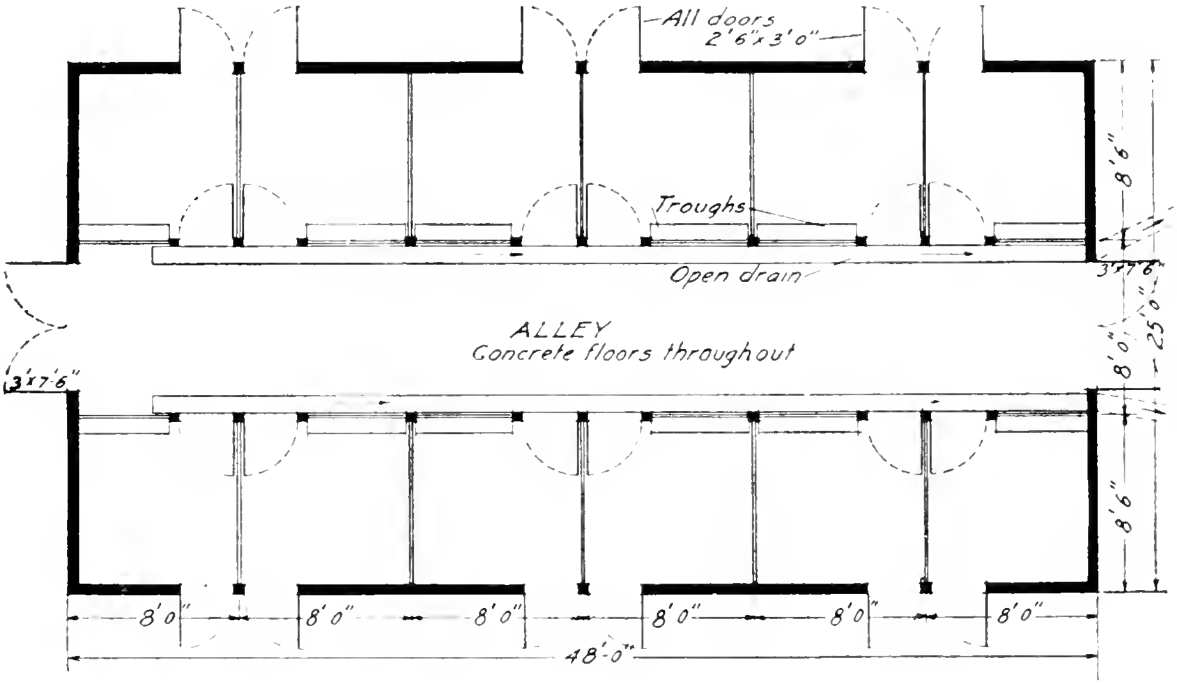

FIG. 271. *A twelve-pen hog house. One pen may be sacrificed for feed bins.*

CHICKEN HOUSE

Construction. A chicken house is designed to be a housing for fowls which will provide protection against wind and cold, furnish a place for laying hens, room for roosts, and room for feeding and watering devices. The house should provide 2 to 5 square feet of floor space per bird. The glass surface should be 5 to 10 per cent of the floor space, and 20 per cent of the opening should be covered with muslin rather than glass. Roosts should be made of 2×3's or 2×4's with the corners rounded. They should all be the same height, 12 to 14 inches apart, provide 8 inches of perch space for each bird, and be placed 10 inches above the dropping board, which should be 2 feet 6 inches above the floor. Dropping board and perches should be made movable to facilitate cleaning. Nests should be provided at the rate of one for three to five hens and should be 12 × 12 × 16 inches in size and at least 12 inches from the floor. The roof may be of any type desired, but should be tight.

SILO

General considerations. The value of the silo on the modern stock farm has been thoroughly demonstrated, and since a discussion along the line of its advantages falls within the province of animal husbandry, it will not be considered in this chapter. The method of silo construction is a question upon which users disagree. It is usually found that the owner of a silo is satisfied with the style of construction which he has used and would not be satisfied with another. There are a few fundamental requirements which are necessary for any silo, regardless of the materials of which it is to be made or local conditions. It should be practically air-tight, since cracks and leaks in the walls always produce spots of spoiled silage. Silo walls should be of impervious material, as it is essential that moisture be retained, and the inside walls of the silo should be smooth in order that friction may not prevent silage along the wall from packing. The silo walls should offer as much protection from feeezing as is possible and must have sufficient strength to prevent bursting when filled. Other characteristics relate to first cost, resistance to fire and wind, durability, and conformity in appearance to the other farm buildings.

The economy of the silo is for herds larger than 10 dairy cows or their equivalent. The requisite of a good silo is air-tightness. In severe climates freezing will occur in all types of silos. No one type can be recommended in preference to all others. The size of a silo depends upon the quantity fed per day and the length of the feeding period. Reinforcement is necessary to resist the bursting pressure. A tight roof is necessary, and doors must be kept closed except for a short interval at feeding time.

Dimensions. The quantity of silage consumed by an average dairy cow is 1 cubic foot, or 40 pounds, per day. The number of days in the year on which silage is fed varies from 180 to 240. The capacity of the silo is rated in tons. Silage spoils by exposure to air, and a depth of at least 2 inches should be fed from the top every day to prevent waste. For determining the size of a silo a diameter should be selected such that one day's feeding of stock will require at least a depth of 2 inches of silage. This may be determined as follows: The area of the silo in square feet, multiplied by 1/6, multiplied by the weight of silage per cubic foot in pounds, equals the total weight fed per day in pounds. This statement may be reduced to the following rule: To obtain the diameter of the silo, extract the square root of the product of the number of cows multiplied by 7½. To determine the height, multiply 2 inches by the number of days on which silage is to be fed. For example, to find the size of a silo required to feed 50 cows for 200 days: 50×7½=375. The square root of 375 is 19.4. Therefore 19.4 feet is the proper diameter. Since odd sizes are not made, the nearest commercial diameter to 19.4 is 20 feet.

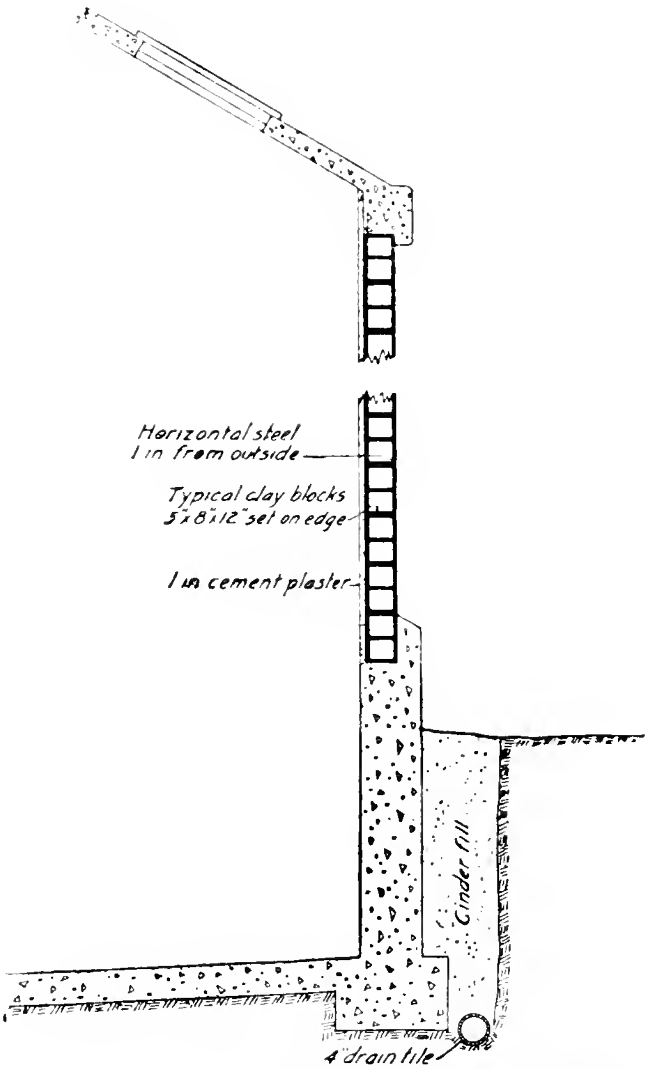

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FIG. 272. *Wall section of hollow-block silo*

Since 2 inches of silage must be fed per day, the height should be 200×2, or 33⅓ feet. The nearest commercial height would be 34 feet. It is customary to make the height approximately double the diameter; when the diameter computed by the above rule gives too low a silo, the height can be increased and the diameter decreased, the capacity in cubic feet being kept the same.

Bursting strain. Silage is supposed to exert a pressure of 11 pounds per square foot per vertical foot of head. Consequently the pressure per square foot on the silo walls at any point is equivalent to the head of silage above that point multiplied by 11. For determining the size of reinforcement or hoops, the cross section of steel used for each vertical foot should be equivalent to .000344 multiplied by the head of silage in feet above the given point, multiplied by the inside diameter of the silo in feet. This rule applies to all styles of silos. It is customary to consider that the steel carries the entire bursting stress regardless of other materials. For example, to find the size of hoops required for a 12-foot wooden silo or the extent of reinforcing for a 12-foot concrete silo 20 feet below the top: $.000344 \times 20 \times 12 = .082$. The cross section would therefore be .082 square inch, which would require for each foot six ⅛-inch square rods or two ¼-inch round rods.

Freezing. Experimental data tend to show that in severe winters freezing will occur in any type of silo unless great expense, which is not ordinarily justifiable, is incurred for double walls. A considerable percentage of freezing in silos is caused by the useless circulation of air through them as a result of a poor roof or of leaving the doors open. If the weather is very cold, a canvas or straw covering should be spread over the top of the silage and the doors kept closed except at feeding time.

Home construction. Silos can be purchased in a number of ways. Manufacturers will send an expert superintendent to erect a silo, or the materials may be purchased and erected by the landowner or by a local mechanic. Where the distance of travel is not too great, it is usually advisable to have the silo, regardless of its type, erected by a man who thoroughly understands that particular line of work. The advisability of a landowner building his own silo will depend upon his mechanical ability, equipment, and help available.

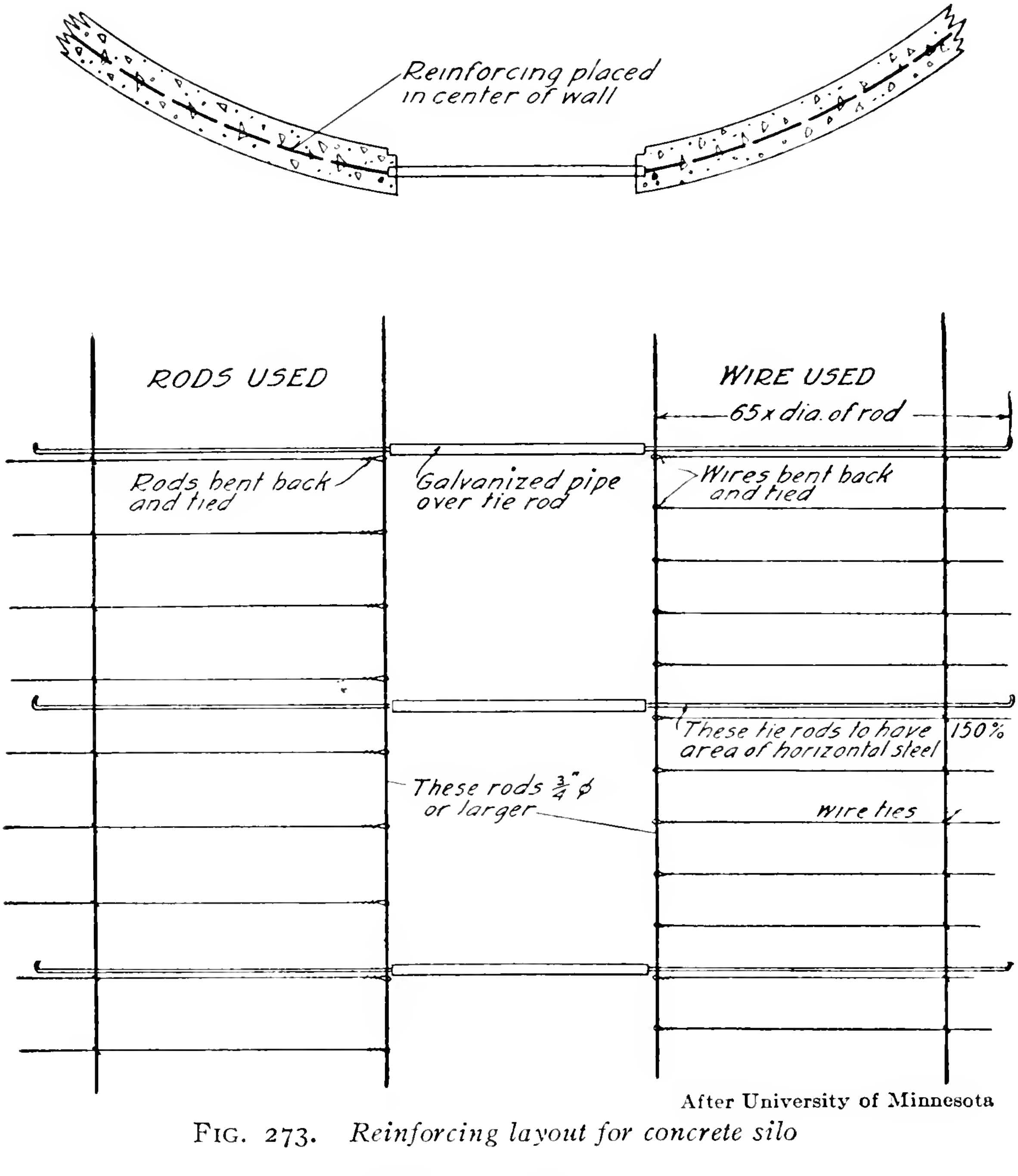

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FIG. 273. *Reinforcing layout for concrete silo*

Foundation. The foundation of a silo should be placed on solid ground and be of sufficient depth to prevent heaving by frost (Fig. 274). The roof should be made of some material that is in conformity with the silo walls and should be as near air-tight as practicable. Where winters are long and severe, a style of door should be selected which will open and close readily so that there will be no temptation to leave the door open for a long period and permit the inlet of a large quantity of cold air.

Material. *Wooden silos* (Fig. 275) are used all over the country. From the standpoint of preservation of the silage they are satisfactory. However, wood silos can be destoyed by fire, and when they are empty their walls may shrink and render them subject to damage by windstorms. This can be prevented if the hoops are kept tight. The shrinkage objection in a stave silo may be avoided if the walls are made of panels placed between upright studs. *Wood-hoop silos* (Fig. 276) are frequently built, and they readily lend themselves to home construction, as the materials can be secured at local lumber yards. *Steel* is used for silo construction.

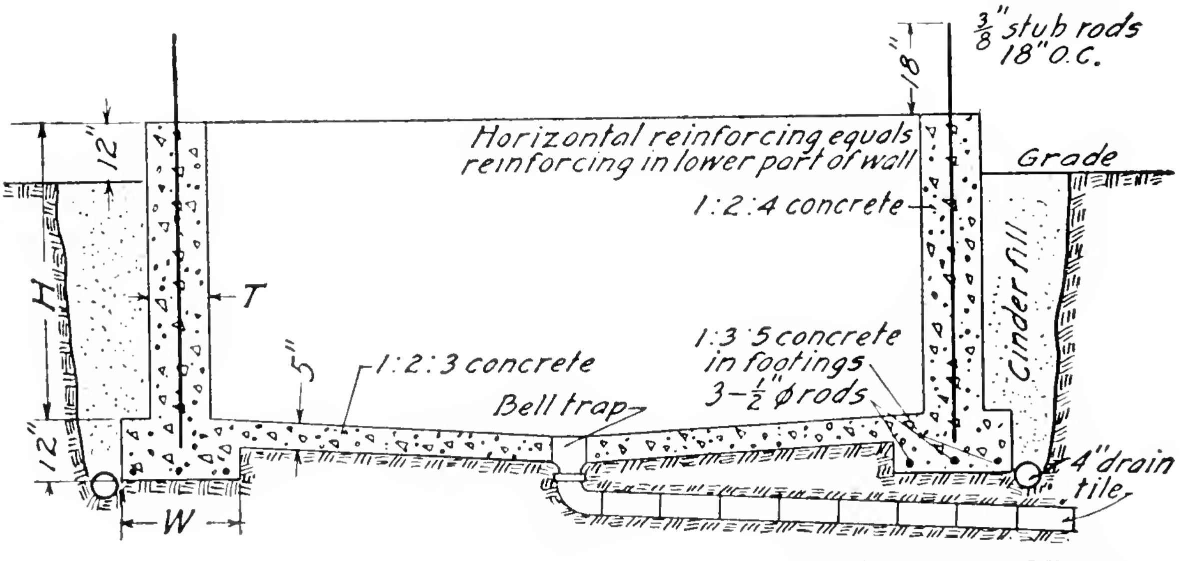

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FIG. 274. *Recommended practice for silo foundation*

For wooden silos:
H—2′ 0″ to 6′ 0″
T—6″ reinforced
T—12″ without reinforcing
W—14″ for most soils
W—16″ for wet clay or similar poorly bearing soils

For concrete, cement block, masonry, or clay-block silos:
T—8″ up to 30′ high
T—12″ for height exceeding 30′
W—16″ up to 30′ in good soil
W—2′ 0″ up to 30′ high in wet clay, etc.
W—20″ over 30′ high in good soil
W—2′ to 2′ 6″ over 30′ high in wet clay, etc.

In cold climates a single wall of steel does not afford protection from frost, but a double steel wall with tight air spaces is entirely practical. *Clay tile*, *concrete blocks*, and *concrete* *staves* are used in localities where these materials are available. Any of these makes a permanent, neat, and satisfactory silo. *Monolithic concrete silos* are preferred by some

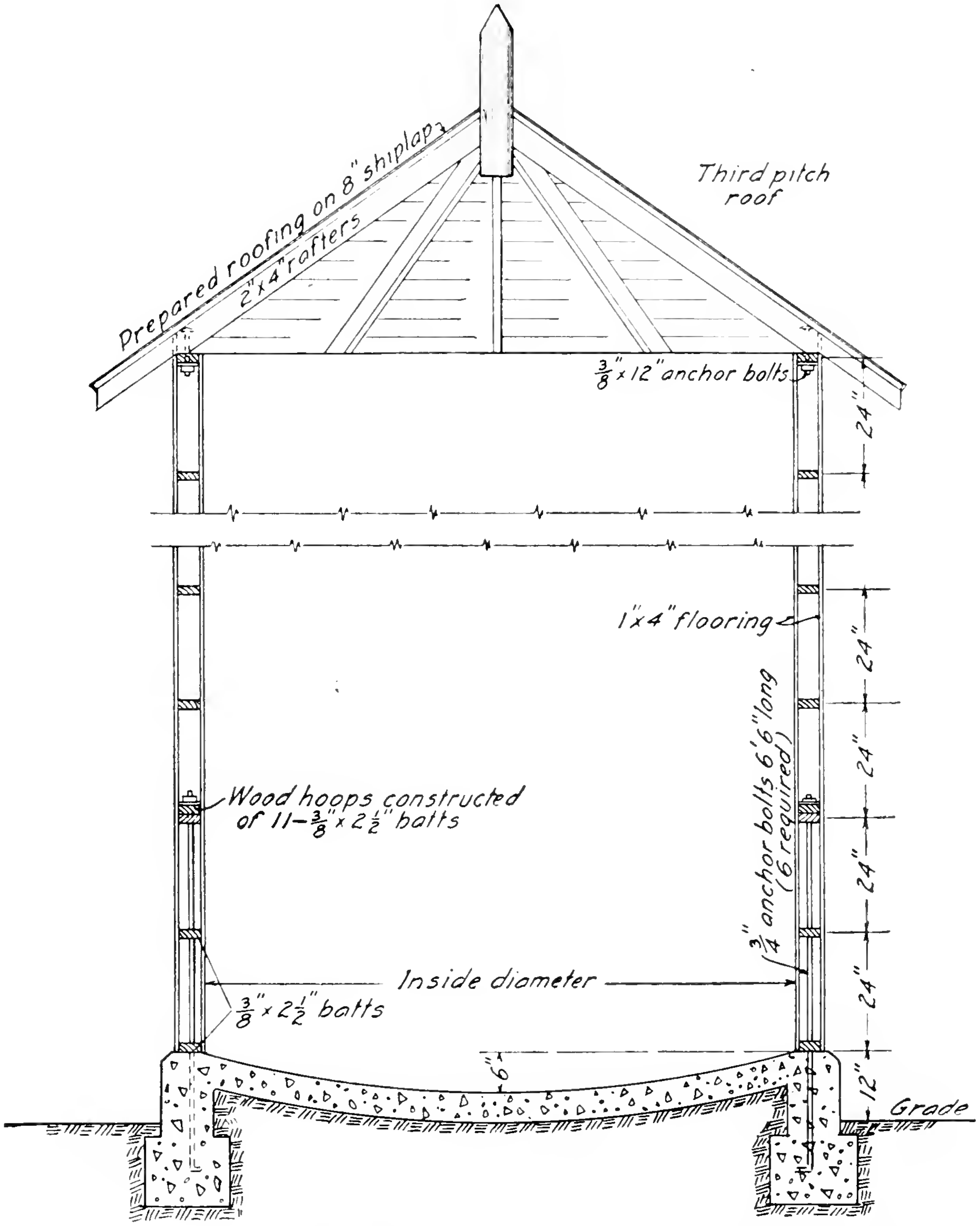

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FIG. 275. *Wood silo using built-up wood hoops*

land-owners. They are permanent and satisfactory when once constructed. The choice of an individual type depends upon the taste of the landowner, the character of the

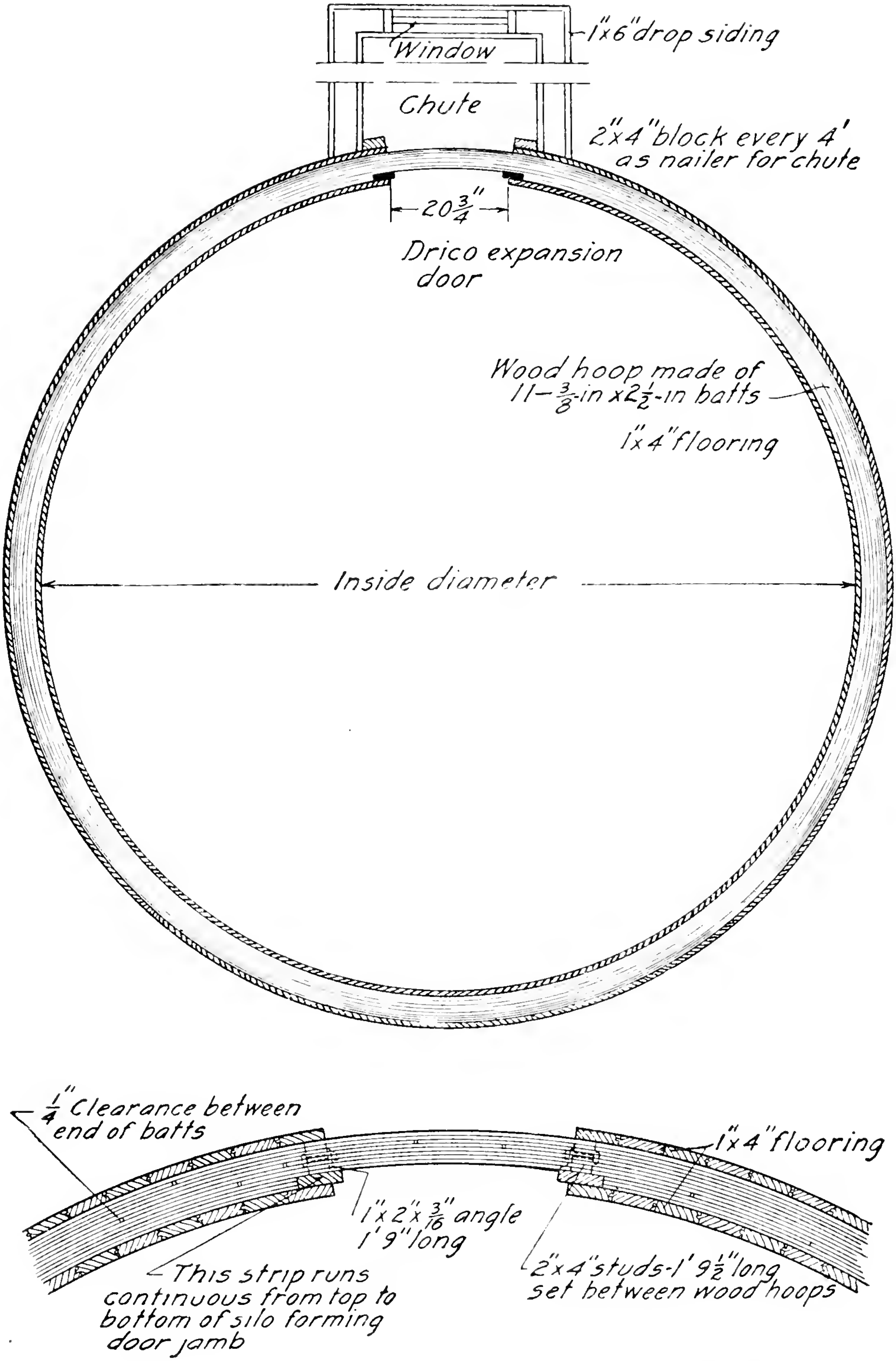

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FIG. 276. *Wood hoop and detail of construction around door*

other farm buildings, and the amount of money available for the initial cost.

GRANARIES

The chief characteristics of a good granary are strength of floors and walls and provision for keeping out mice and rats. The supports or joists may be provided for as any beam is designed. The load on side walls may be determined by the following formula:

$$L\times\frac{H}{2}\times G\times\frac{2}{3}$$

in which L is the length of the side wall, H, the height of the wall, and G, the weight of a cubic foot of the grain to be contained. A cubic foot contains approximately 4/5 bushel. One bushel occupies approximately 1¼ cubic feet of space. The size of the granary may be figured from the maximum quantity that it is desired to store. It is, many times, convenient to provide a hopper bottom in grain bins. While this is an added expense, it may be desirable. The minimum slope is 2½ feet rise in 8 feet run. In a country where corn is one of the leading crops, the granary may be combined with a double crib as illustrated in Figure 277.

CORN CRIBS

The width of the corn crib is determined by the penetration and cooling effect of the outside atmosphere. Five to nine feet is standard practice. The height is usually 10 feet, although it may be higher if conveniences are at hand for elevating the corn. One bushel of ear corn occupies about 2¼ cubic feet. Where any considerable quantity of corn is raised, the double crib is generally given preference over the single. The overhead granary is an added advantage in this type. Nine feet is a good width for the driveway and serves admirably for the housing of wagons and buggies. If it is desired to accommodate special machinery, a greater width may be provided. Arrangement must be made for dumping machinery; an opening near the center of the roof ridge—preferably protected by a cupola—will give access to both granary and cribs.

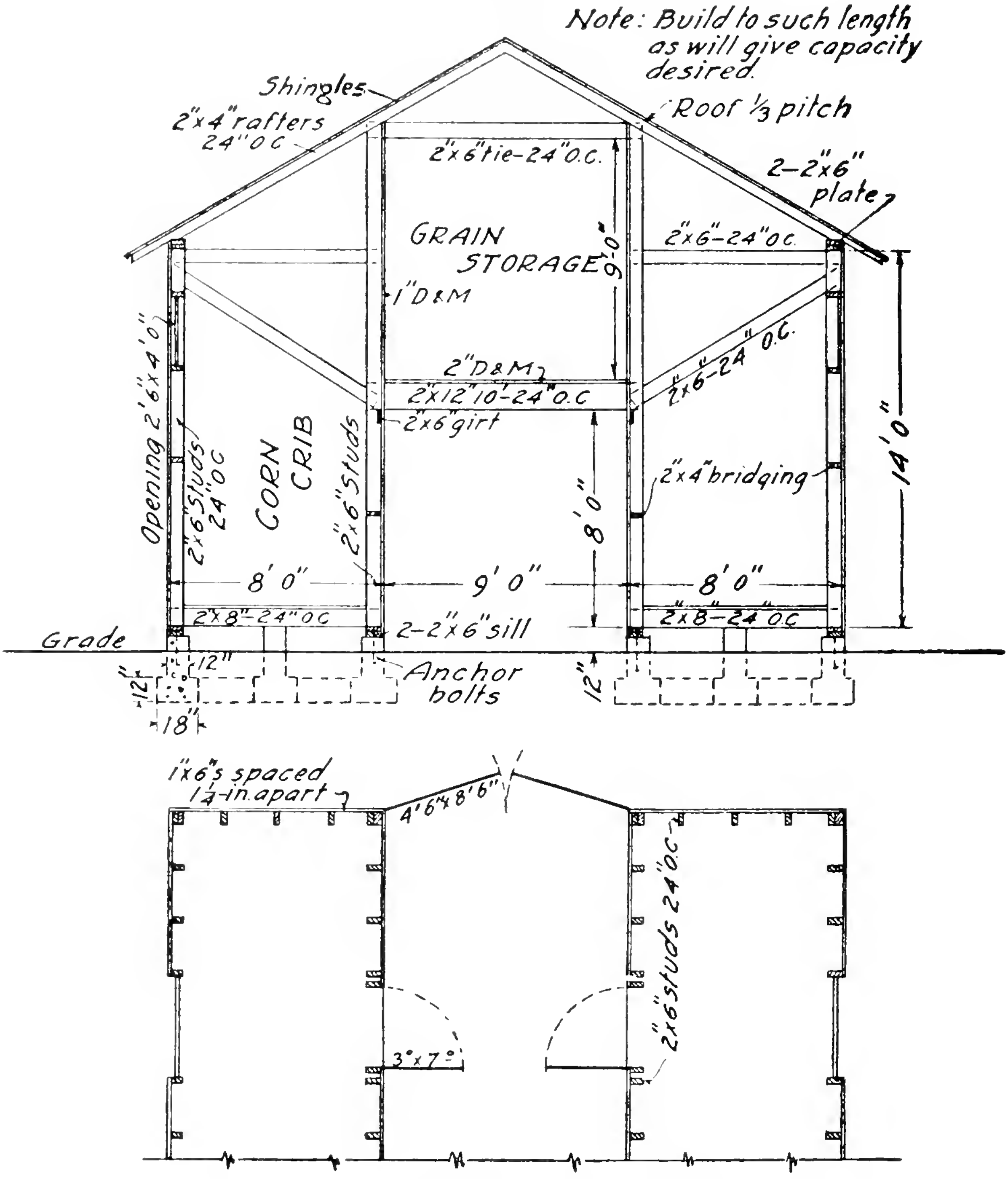


FIG. 277. *Combination corn crib and granary*

ROOT CELLAR

A root cellar (Fig. 278) for the storage of potatoes or roots used in feeding dairy stock over a part or all of the winter in many sections is looked upon as a necessary part of the farm equipment. The essential feature of such a building is protection from frost and the ease with which the root crop

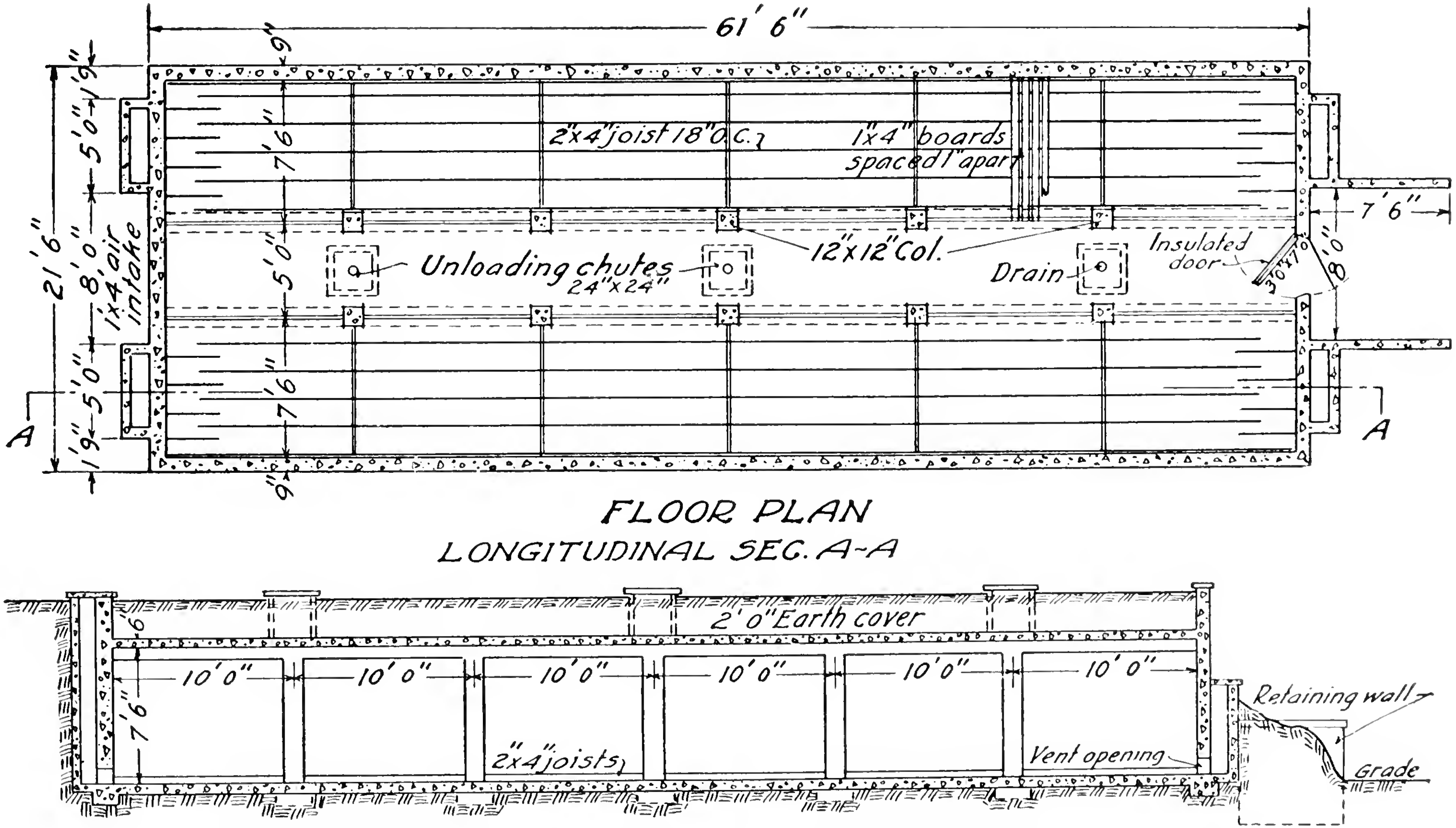
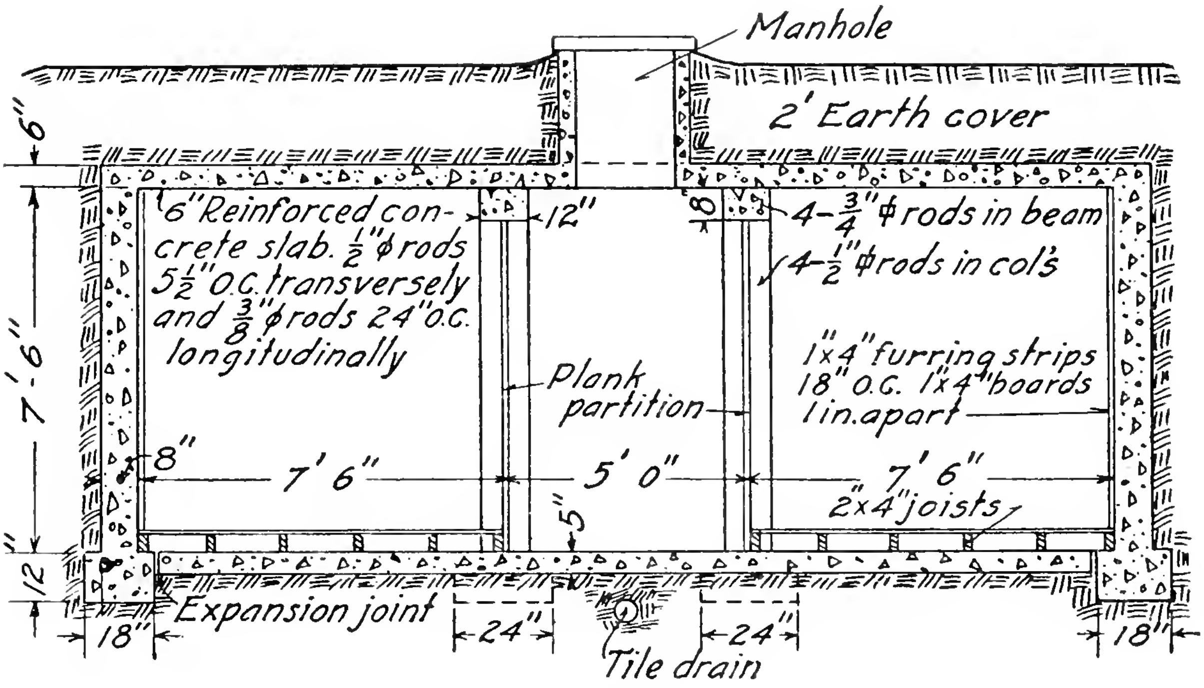
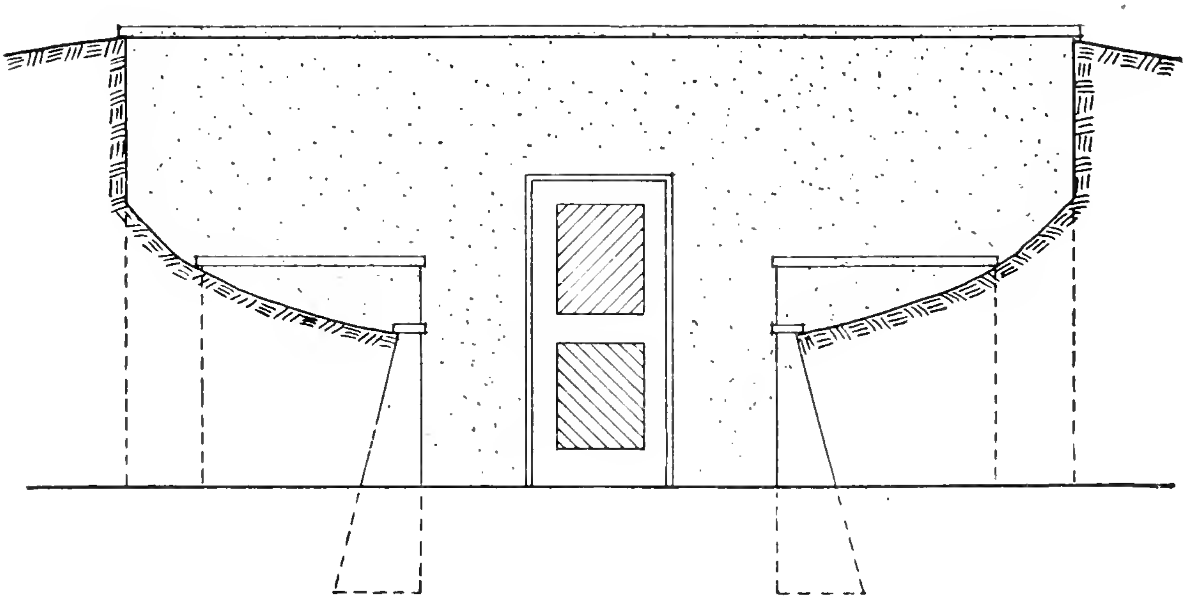


FIG. 278. *Longitudinal section and plan for concrete root-storage cellar, 2500 bushels*

can be placed in storage and taken out when needed. The most suitable construction for this purpose has been found to be of concrete, entirely or partially built underground



Cross Section



Front Elevation

FIG. 279. *Cross section and front elevation of root cellar*

with sufficient earth placed over the top to render it frost-proof. The top should be of sufficient strength to permit a wagon to be driven up to unloading chutes unless the cellar is of a size that will permit a wagon to be driven or backed into the main passageway. Good drainage of the floor and foundation is essential. The floor, if well drained, may be of earth, but concrete is better. The walls are concrete and the roof reinforced concrete.

MACHINE SHEDS

A machine shed is desirable and a paying investment when designed so that the cost is within approximately 15 per cent of the value of the machinery housed. When designing a machine shed, it is necessary to gather the implements together and make rearrangements of them in order that the floor space may be most economically utilized. The minimum depth for a machine shed is approximately 20 feet. The distance between supports must be wide enough for the widest implement to pass through, or wide enough for two smaller ones to pass through abreast. The value of the machine shed lies in the ease with which a machine can be put in and taken out. This is best accomplished if one entire side is made of slide doors such that one slides on the outside and the adjacent one on the inside. The agricultural implements make rather expensive chicken roosts. To prevent such use of them, there must be doors on the machine shed that come sufficiently close to the ground to keep poultry from crawling under. As the sheeting of the shed decays very rapidly when in contact with the ground, it is advisable to use a horizontal timber close to the ground. This may be creosoted or otherwise treated to extend its life. Being horizontal, it can be cheaply and conveniently replaced from time to time as it deteriorates. The same method may be applied to the bottom of the doors. A suggestion to combine a machine shed and chicken house, back to back, offers an opportunity for the saving of some material, as well as providing a protection for the cold side of the chicken house.

GARAGE

The size of a garage for a single machine should be the length of the car, plus at least 4 feet, and preferably 6 feet.

The width should not be less than 12 feet. This will allow room for the incidental repair work and attentions necessary. The minimum size for a garage may be placed at 12×16 feet. This will accommodate very comfortably the smaller machines.

The style may be very plain or may be embellished to harmonize with the architectural features of surrounding buildings. The doors should be 8×8 feet or very nearly this size. The style of door may be single-swing, double-swing, sliding, or any of the patent doors. The single-swing door is too heavy for most hinges. It will sag unless very strongly braced. The double-swing is probably the most common, while the sliding door is the most convenient, although not the nearest weather-proof. Swinging doors must be provided with anchorage to prevent their being blown shut at a time when a car is being run in or out. While a window is an added expense, the light is a great advantage when one is working with the car and reduces the temptation to strike a match rather than get a flashlight or roll the car out into the open. The garage is probably the most convenient place to store gasoline and oil. When it is used for this purpose, additional space must be provided. A pit 3×4 feet in size and 2 to 2½ feet deep is favored by some, but it invites accidents and is hardly to be recommended. As a substitute for the convenience of the pit into which to get while working on the under side of a gasoline motor, the creeper may be used. This is a board or slatted panel 18×48 inches, with good-sized castors at the corners. With this convenience, repairs may be made even more easily than with a pit.

REPAIR SHOP

A repair shop (Fig. 280) in conjunction with or in close proximity to the machine shed is a great convenience. The provision for protection against fire is important. A forge shop and a carpenter shop can hardly be considered as compatible occupants of the same room. Shavings and wood

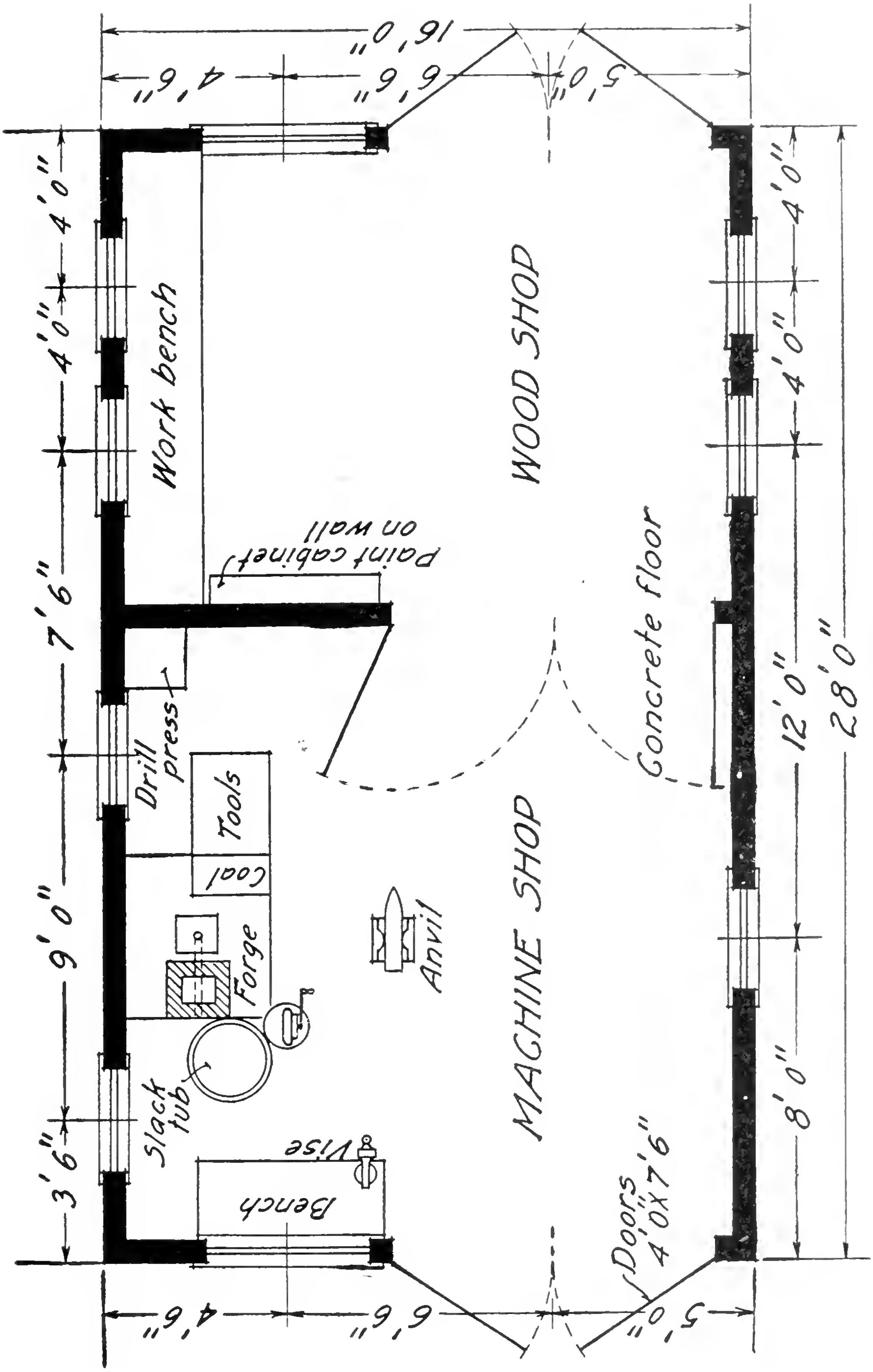


FIG. 280. Floor plan for repair shop

waste are very easily fired by sparks from a forge. The shop should be large enough to take in all but the largest of the agricultural machines. This will make it possible to care for all repairs during the winter months.

ICE HOUSE

Ice weighs 57 pounds per cubic foot; 40 cubic feet are allowed per ton, which includes the packing about the ice. The average ice box, as used in the kitchen, consumes about 5 tons of ice per year. The size of ice house may readily be estimated. It is hardly reasonable to spend a great deal of money on an ice house. The essential thing is to have a shell which will retain the packing material, sawdust, straw, or ground cork up against the ice pack and allow the packing to remain dry. The ice is placed in a room in a solid cake, as near as possible, a space of 16 to 20 inches being left all around, which is later filled with the packing or insulating material. If it is desirable to build what is called an insulating ice house, which may be used in conjunction with an adjacent cooling room or refrigerator, it will be necessary to

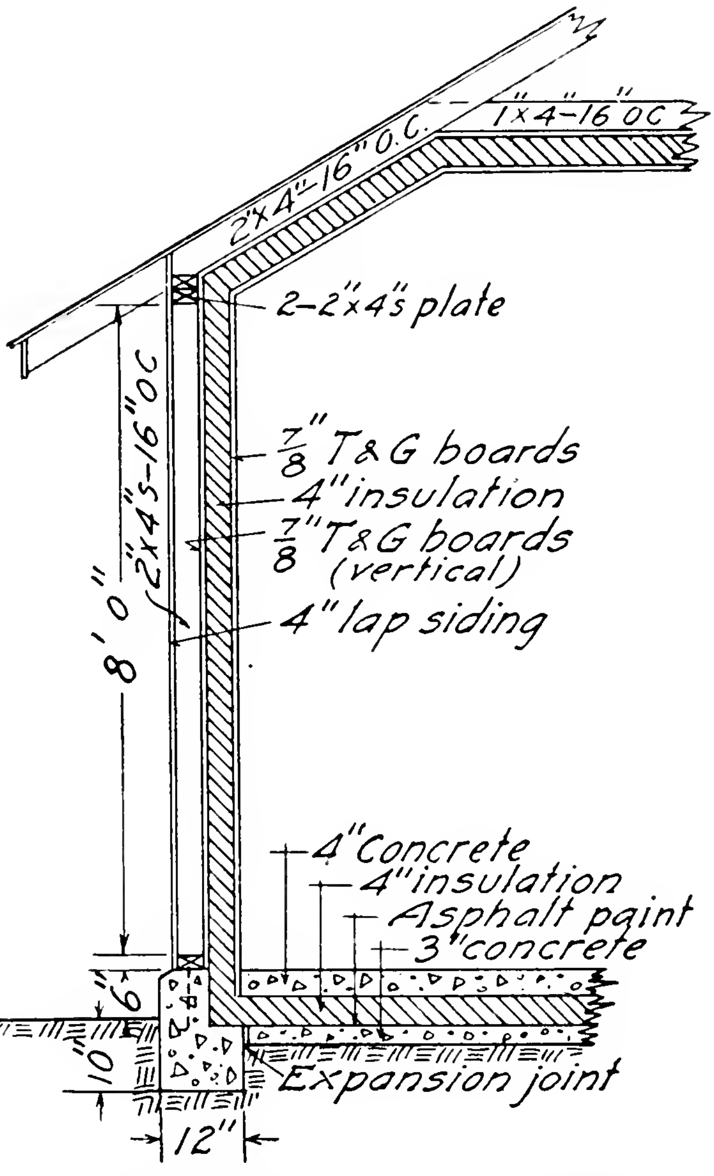


FIG. 281. *Cross section A-A of ice-storage room (shown in Fig. 282) to be used in connection with milk house*

insulate the walls sufficiently to make the 16 or 20 inches of packing unnecessary. Any ice house should be provided with good drainage, for when insulating material gets wet, it looses its efficacy very materially. An ice house of any type should have a large air space above the ice pack to provide for the removal of the air which becomes hot when the sun beats upon the roof.

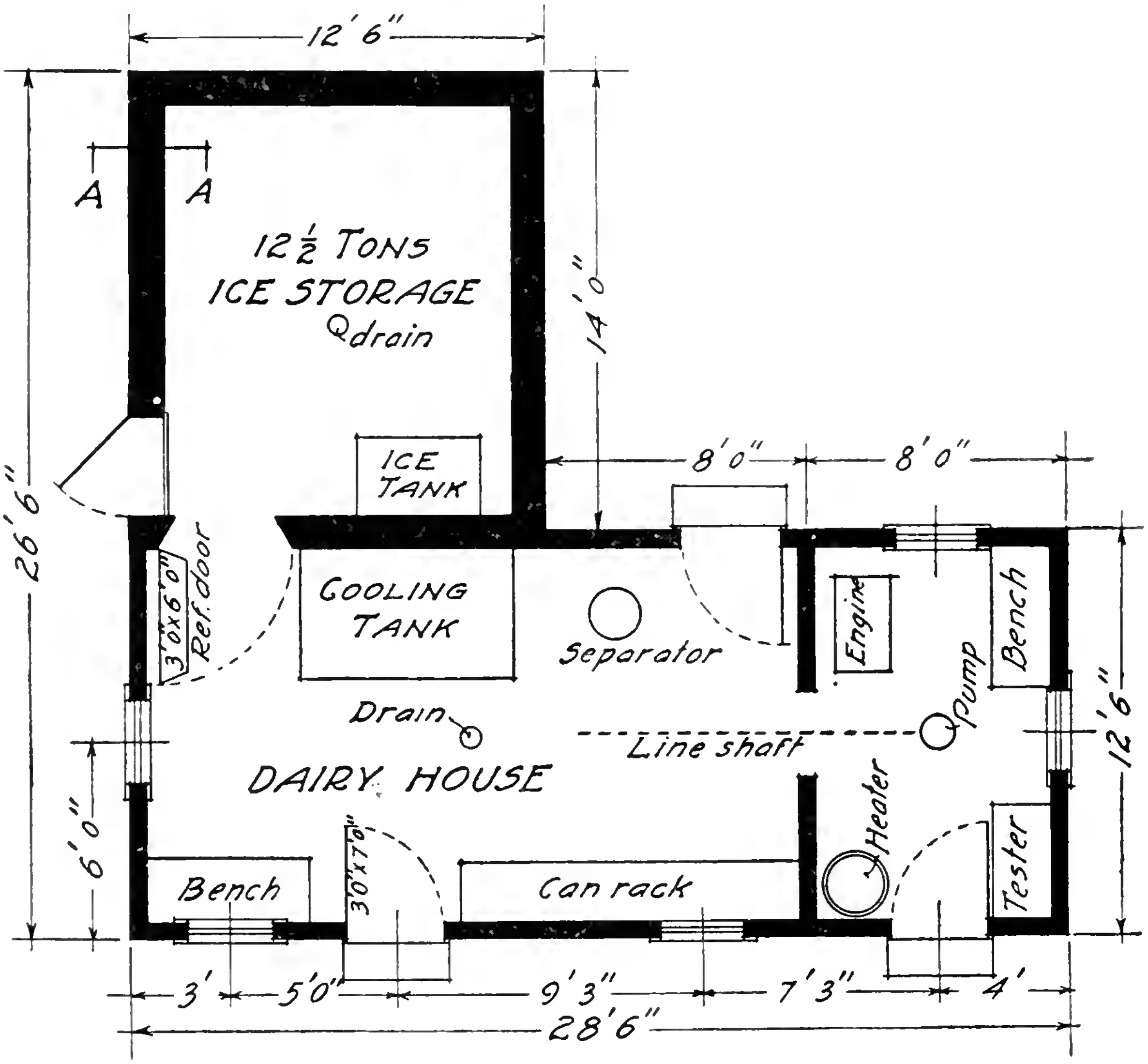


FIG. 282. *Floor plan of dairy and ice-storage house combined*

MILK HOUSE

A milk house is intended to be a combination of cooling room, storage room, and washing plant, in which the operations may be carried on which ordinarily are conducted in the kitchen and cellar. The equipment of the milk house will include a tank, which will contain water for cooling the milk and provision for washing. The cooling temperature may be maintained by fresh water pumped to the tank or simply by the addition of ice. The cooling tank should be near the sink or table at which the washing and sterilizing are to be done. The separator is most conveniently placed in this same room. A separate room should contain a tank heater and fuel supply, which will provide hot water, preferably under some pressure.

Milk houses are, at present, built separate, in conjunction with the barn, and in conjunction with the ice house. When they are built in conjunction with the ice house (Fig. 282), it will still be necessary to use a cooling tank, as it is not advisable to place fresh uncooled milk in the cooling room of an insulated ice house.

SUMMARY

The plans and suggestions in this chapter are not intended to be complete and satisfactory for any given locality, but are merely to call attention to dimensions and general principles that must be taken into consideration in the planning and construction of buildings with any of the ordinary materials and for varying climates and farm purposes.

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CHAPTER XVII

WATER SUPPLY

Source of supply. There are two sources from which a supply of water may be obtained for farm use: surface water, collected in lakes, ponds, or streams; and ground water, found in certain strata of the soil, in caverns, in beds, or in fractures of the earth's shell.

Surface waters are very open to pollution and for this reason are not generally used for consumption in the home, although when conveniently located they may prove quite suitable for the farm animals. Springs may be of deep origin or almost entirely surface water. They are subject to pollution at a distance or from immediate washing into the spring bed and are not to be considered safe, pure waters simply because they appear as springs. Local protection of a spring is comparatively simple, but it is a difficult matter either to locate or to prevent pollution at a distance. Of the ground waters the most desirable are those found in sand or gravel strata, for they have passed through many feet of natural filter. Ground waters are usually accessible only through the medium of wells, with or without pumps to extract the water.

Wells. *Shallow.* The dug or shallow well is usually limited to 30 or 40 feet in depth and 3 to 6 feet in diameter. It may be curbed from the solid rock, with rock, brick, concrete, or timber. If timber is used, it is desirable that the lagging be placed vertically for the top 8 feet. The decay of the lagging is most rapid where there is an opportunity for drying out of the wood, to be followed by subsequent wetting and drying. If these members are placed vertically, they may be removed, piece by piece, and replaced without difficulty.

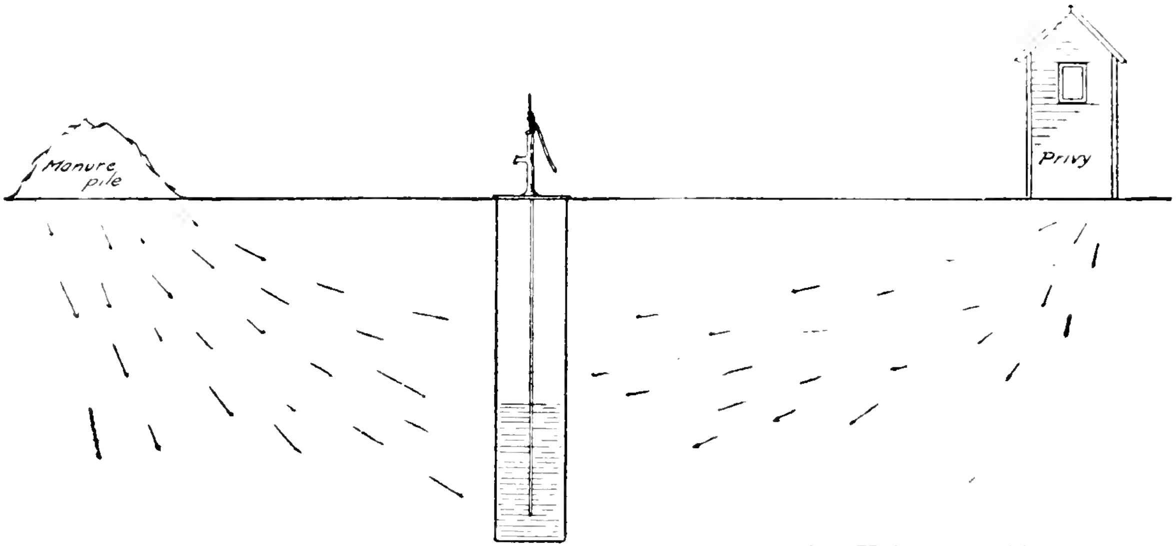
Tubular. A tubular well is generally a driven well. It is seldom more than 150 feet deep and may be used only where the material is soft and reasonably free from bowlders.

Bored. A bored well is made by the use of a large earth auger. It may be from 2 inches to 3 feet in diameter, but is limited in depth to about 100 feet. An auger may be used only in soft earth.

Drilled. The drilled well, which is probably the most common type, is made by the use of heavy steel drills capable of going through any kind of material. Such a well is finished from 2 to 6 inches in diameter and may be 12 inches or larger at the surface; the depth is almost unlimited. It is necessary to case these wells down as far as solid rock.

Artesian. An artesian well may be any type of well thus far mentioned, the peculiarity being that the water rises a considerable distance above the point at which it was struck. An artesian well is not necessarily a flowing well.

Sanitary protection of wells. There are many diseases, such as typhoid fever, the germs of which are transmitted by water. These germs, when deposited on the soil, may be taken up by the rains and thus carried into springs, streams, and wells, and may cause an outbreak of disease several miles away. Any person familiar with farm conditions has undoubtedly noticed the lack of sanitary precautions taken to safeguard the water supply. The well is often located on ground lower than the surrounding buildings, around which are manure-piles and other deposits of filth. It is often lined with a wooden curb or an open wall, and is covered at the surface of the ground with an open plank top. Poultry and small animals pass freely around and over the covering, or wallow in the waste water which stands within a few feet of the well top. Persons coming from the stables, and others with filth and dirt adhering to their shoes, stand on the top while drawing water. As a result, a large quantity of this filth, which accumulates on the cover, is carried into the well by the splash of the water every time a pail is drawn. Each rain carries a large quantity of it from the cover and surrounding soil into the well, through both the top and the open wall, thus making an easy method of carrying into the well disease germs which have been permitted to collect in the vicinity.

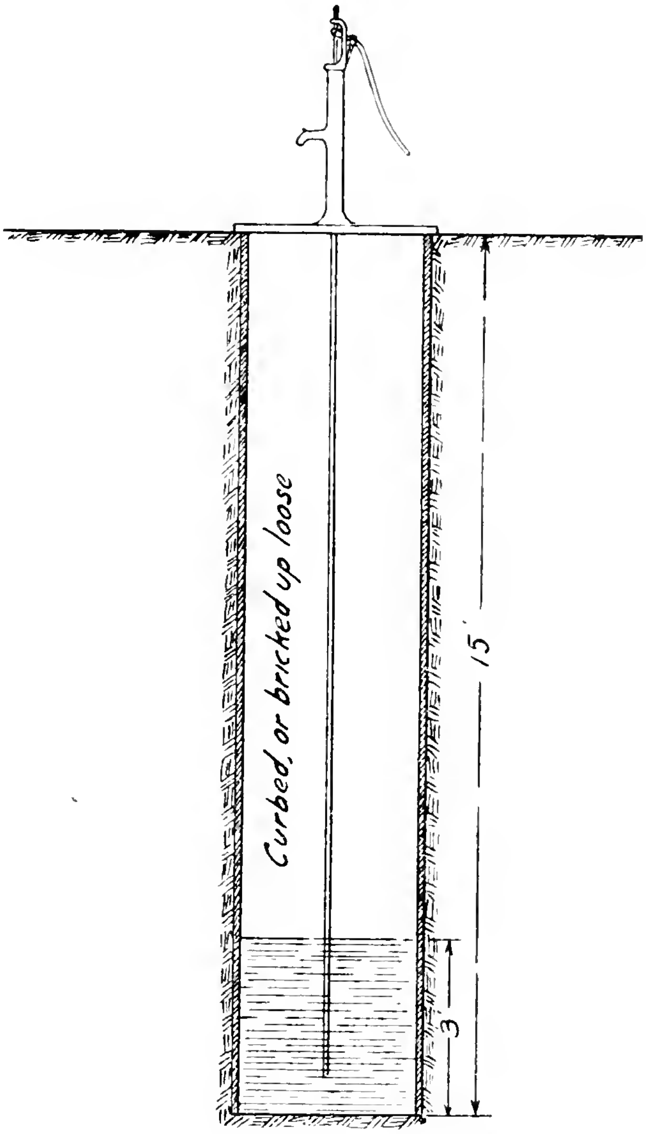


After University of Minnesota

FIG. 283. *In ordinary soil a drain tile laid 3 to 4 feet deep will drain from 50 to 100 feet on either side, and as the depth of the tile is increased the width of the drainage area is also increased. An open well will act on the surrounding area the same as a drain tile. Consequently water leaching through piles of filth lying within this drainage area will quickly find its way into the well as indicated by the arrows.*

The source of pollution of most wells is from direct seepage or leakage from privy vaults, barnyards, and directly through the curbing and covering. The protection from the privy vault may be accomplished most simply by maintenance of a distance of at least 150 feet between the vault and the well. Protection against surface leakage may be secured by means of grading up around the well 8 to 12 inches with a radius of 10 to 15 feet, using a hard, impervious clay, and then building a concrete slab which allows of no direct leakage of spilled water and rain back into the well.

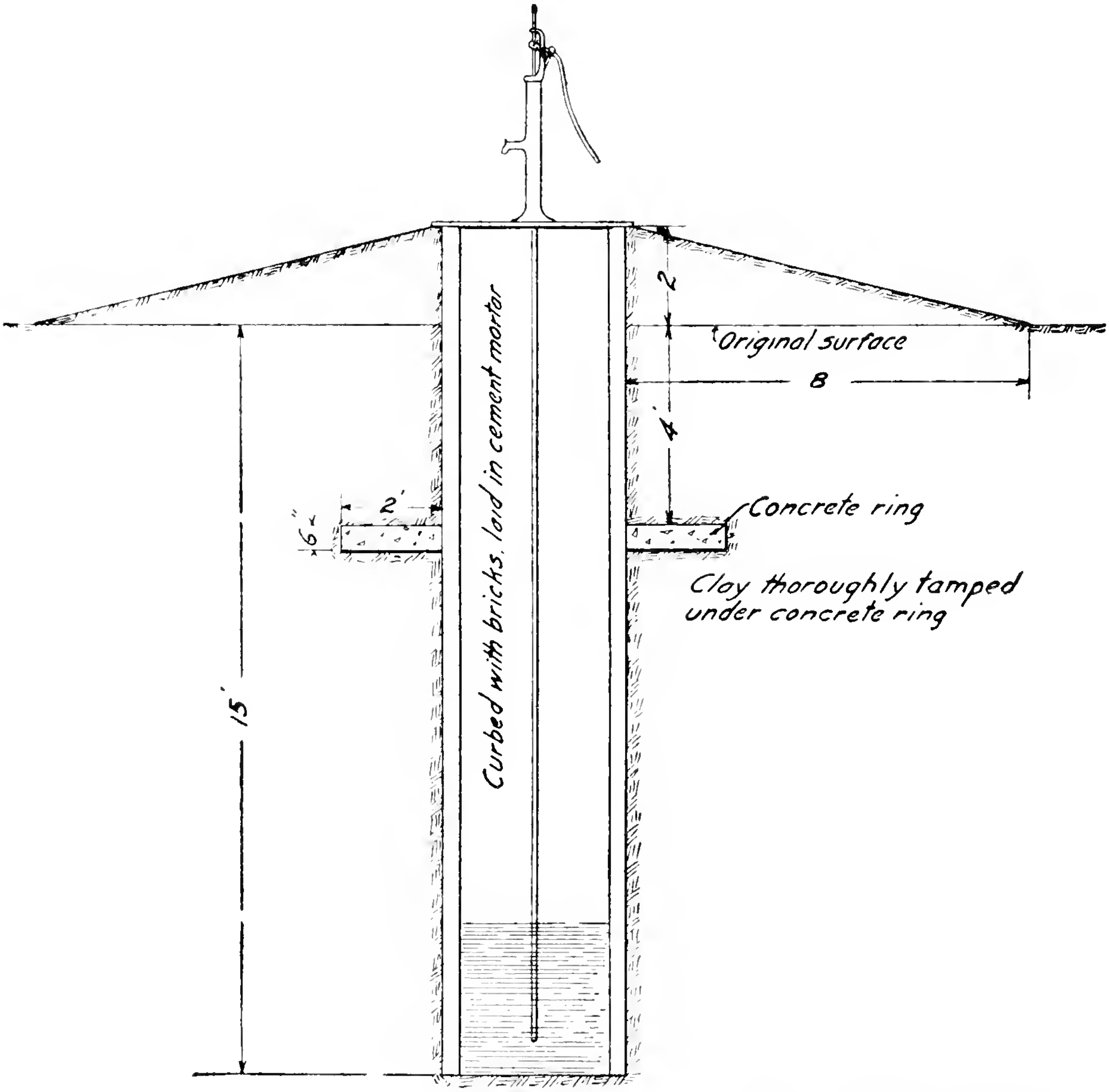
Shallow wells. The well should be located on land higher than the barn and outbuildings, and as far from them as practicable, to prevent water after heavy rains from flowing either over the surface or through the soil toward the well. It should, if possible, be lined on the inside down to the water strata with a water-tight wall. This can be made of large sewer pipe, with cemented joints, or hard brick laid in cement mortar. About 4 feet below the general surface a ring of concrete 6 inches thick should be placed entirely around the wall, and extended back at least a foot into the solid earth which has not been disturbed by the digging of the well. This will prevent surface water from following down the outside of the wall to the water strata. Water readily follows along the straight line of a hard surface, or past a rounded obstruction, but square corners are very effective in stopping such a flow. The top of the wall should extend above the general surface, and enough filling should be added to form a gentle slope away from the top.



After University of Minnesota

FIG. 284. *Ordinary method of constructing shallow wells. Water flowing over the surface or filtering down through the ground can follow along the wall and enter the well at any point above the water line; also waste water from the pump will go through the top and down into the well.*

Care should be used in the construction of the top of the well. The best is a brick arch or a reinforced concrete cover, with two openings, one sufficient to accommodate the pump and the other, not less than 20 inches in diameter, to admit a man in case cleaning or repairs are necessary in the well after the top is completed and the pump put in place. Some method should be used to make these openings water-tight. This is much more easily accomplished if a raised projection is made around the openings. If a wooden top is used, it should



After University of Minnesota

FIG. 285. *Showing proper method of constructing a shallow well. At approximately 4 feet from surface a ring of concrete has been placed around the wall. This prevents the passage of water along the wall, while the hard brick laid in cement mortar prevents access of water through the wall. The sloping surface around the top throws all drainage water and waste water from the pump away from the well. The sanitary condition of such a well is vastly superior to that of the well shown in Fig. 284.*

be made of two thicknesses of plank, with overlapping joints, care being taken to fit it tightly on top of the wall to prevent the entrance of small insects; and water should be prevented from flowing through the openings by raised cleats or strips of tin. Dealers in sewer supplies handle cast rings and covers that are convenient for the manhole in a well cover. Metal well covers have been made and placed on the market, but are used only to a limited extent.

If at all practicable, the well should go down through a stratum of clay or rock which does not permit the passage of water. Where the wall passes through such a stratum, the 6-inch ring of concrete should extend from the wall into the face of this stratum. This cuts off all downward seepage of surface water in the vicinity of the well. Such a well will be much less liable to contamination than one dug through porous material only. Since the outbreak of contagious diseases has in numerous instances been traced to surface wells, every possible means should be taken to prevent any contamination of the underground stratum which furnishes the household with water.

Deep wells. As the development of an agricultural district improves, there is a tendency to replace shallow wells with deep wells 2 to 6 inches in diameter and 75 to 200 feet below the surface. Such wells usually penetrate deep strata of impervious material before reaching water, and there is almost no danger of contamination from surface drainage. If there is a large opening on the outside of the pipe or a very porous soil, it might be feasible to fill this opening with thin cement mortar at the time of the completion of the well or to excavate down a few feet and place a ring of concrete around the tube. Ordinarily, however, such precautions are not necessary for the reason that water, attempting to work down the pipe to such a great depth, will carry sand and silt with it, which will permanently seal any opening outside of the tube. The only means by which such a water supply can become polluted is by turning drainage water into one of these wells, or by having the water strata at some distant point above the well come to the surface; but such a condition seldom exists. These small, deep wells are to be recommended for improving sanitary conditions wherever they can be had. Since wells of this class contain no reservoir space, in order to furnish a sufficient supply of water it is necessary that an open water-bearing stratum be reached such that the water will flow into the bottom of the tube as rapidly as it is taken out by the pump. Such a condition can usually be determined by means of water poured into the top of the tube. If the tube cannot be filled, it is a fairly good indication that there is a free flow in the water stratum.

Pumps. The ordinary lift pump which may be had in the cast-iron stock is adapted to all types of wells. The size of pipe used is 1¼ and 1½ inches. The stock and cylinder, with about 3 feet of pipe, are included in the regular list price. The size of cylinder used will depend upon the height that the water must be lifted. By the use of the figure .43 of a pound per square inch of area of the plunger for each foot that the water must be raised, the total power required may be determined. The number of strokes per minute which a pump plunger may make is limited by a piston travel of about 100 feet per minute.

The market offers three types of pump cylinders: cast-iron, cast-iron with brass lining, and a solid brass shell. The cast-iron is the cheapest, and is only about half as efficient as the brass or the brass-lined. The virtue of the brass cylinder is that it does not corrode and roughen. With any variety of water storage, it becomes necessary to use a force pump. Such pumps usually have a longer stroke than the ordinary lift pump. They also have provision for diverting the water at a point several feet below the ground surface. This does away with the danger of freezing. The efficiency of the pump cylinder is seldom more than 50 or 60 per cent. The height that a pump will draw or suck water is limited to about 20 feet. If the pump were 100 per cent efficient, it would be able to draw it about 34 feet. The height to which a pump may lift water is limited only by the strength of the materials used in cylinder, plunger, and pipes, together with the power available. A gas engine or a windmill will work in any storage system, pumping air or water or both.

Daily consumption. The quantity of water which must be provided for different animals per day and for house consumption is shown, approximately, in the following table:

Horse	3½–7	gallons per day
Cow	8½–12	" " "
Hog	1 – 3	" " "
Sheep	1 – 3	" " "
House with water and sink, per person	12	" " "
House with sink, bath, and laundry, per person	30	" " "

The large variation in the quantity of water required by animals is occasioned by the weather, the nature of the feed, and — in the case of the horse — the work being done.

The gravity tank. A tank, or several barrels, located at any convenient place about as high as the attic floor, will force water as high as it needs to go for all house fixtures. It will be of little value for protection against fire. Sufficient pressure is provided by an elevated tank outside, but this is much exposed to frost and is not popular in the North where the winters are as in Minnesota severe. Figure 286 shows a very simple and inexpensive water provision. This will supply the kitchen and laundry, or, by use of 14-foot posts, it is adequate for the upper floor. A tank in the attic is not likely to freeze, but it will sweat and may run over, may leak, and is very heavy if large enough to supply all needs. A tank

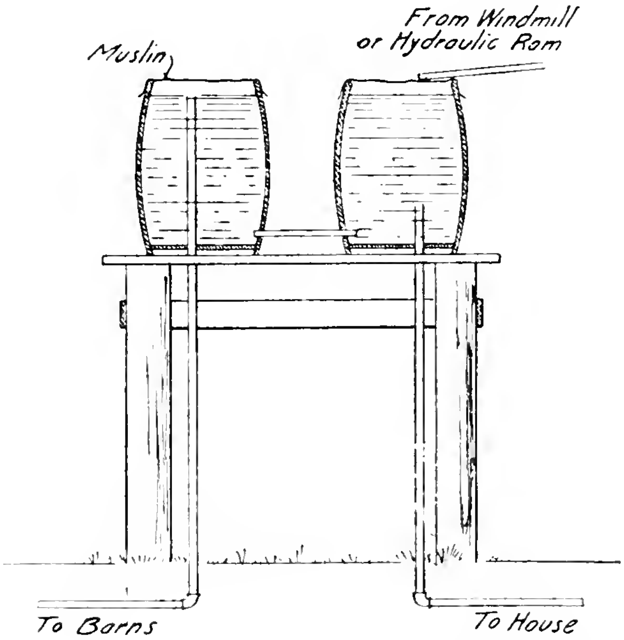


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FIG. 286. *A six-dollar water supply*

should provide about two days' supply. A galvanized iron pan under the attic tank will care for sweat and overflow if provided with an outlet to the sink or the outside. As water weighs 62½ pounds per cubic foot, which is equivalent to 7½ gallons, care must be taken to provide supports adequate for the weight of a tank of water. Two hundred fifty gallons occupy about 36 cubic feet and weigh a ton. This added weight on the attic floor will cause settling in any ordinary house.

A wood or iron tank elevated in one end of a barn is subject to leaks and sweating and is, therefore, not very popular. A tank in either house or barn is subject to freezing, and insulation makes it very difficult to locate and repair leaks. Probably a reinforced concrete tank, with a commercial insulation, or with a light wood jacket, providing space for 8 to 12 inches of dry mill shavings, would meet the requirements. The chief objection to this is the enormous weight of the tank itself. The tank is not high and can be amply supported.

A concrete, clay-block, or masonry silo offers opportunities for an elevated tank which is well taken care of as regards support and reasonably well provided for with respect to freezing from below. It does, however, need protection at the sides and on top. To supply this, it becomes necessary to protect the insulation from the weather, which is not necessary when the tank is under the roof of the barn. Any kind of insulation, other than cork, will absorb moisture and when thoroughly wet is practically worthless.

Where ground-level conditions will permit, the most satisfactory and cheapest installation may be made by means of a concrete cistern built at an elevated point. It is essential that this elevation be sufficient to force the water to the highest point desired. The distance of the cistern should usually not be over 300 feet, as the friction in a length of pipe greater than this will be such as to reduce the flow of water very materially. Freezing will not affect a cistern of this type, and no protection is needed other than what is necessary to protect it from dirt and the approach of animals.

Hydropneumatic system. The hydropneumatic system (Fig. 287) is intended to overcome the objection to the gravity tank. The installation consists of a tank equipped with pressure gauge, safety valve, water column, and an air pump—all placed in the cellar or in a room away from frost. When water is pumped into the tank, the air is compressed. When the tank is one-quarter full, the pressure is 5 pounds. This will force the water up about 11 feet—not quite to the second story. When the tank is

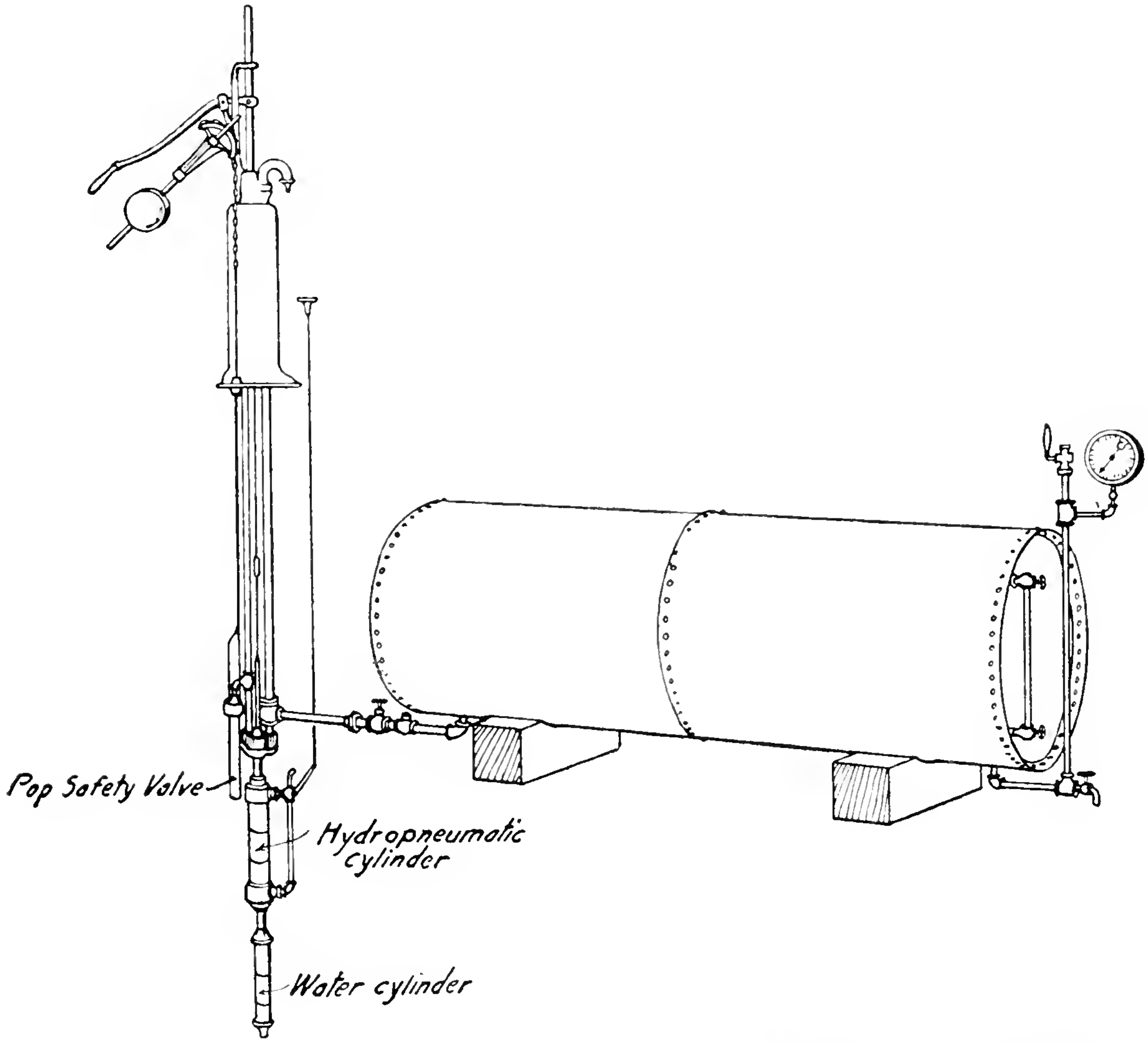

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FIG. 287. *The hydropneumatic system. The air cylinder is a little larger than the water cylinder. If no air is wanted, it may be cut off by the extension rod at the curb.*

half full, the pressure is about 15 pounds, and when three-quarters full, about 45 pounds. Ten pounds' pressure is as little as is of any value, for when water is used the pressure drops very rapidly. It is then necessary to use the air pump and force in more air, in order to utilize all the water in the tank. When the air stands under pressure, it is absorbed by the water and is drawn off when a faucet is opened. This air must be supplied by the air pump. The most convenient scheme is to use a combination of water and air cylinders and make the windmill or engine do both pumping and compressing. Some trouble is encountered in cold weather with the operation of the valves in the hydropneumatic cylinder. It is therefore advisable to protect this cylinder by placing it a little lower in the well, or by a reasonably tight house over the well. A storage tank should be of from 750 to 1,000 gallons' capacity. This will prove very little protection against fire unless the pump is kept running.

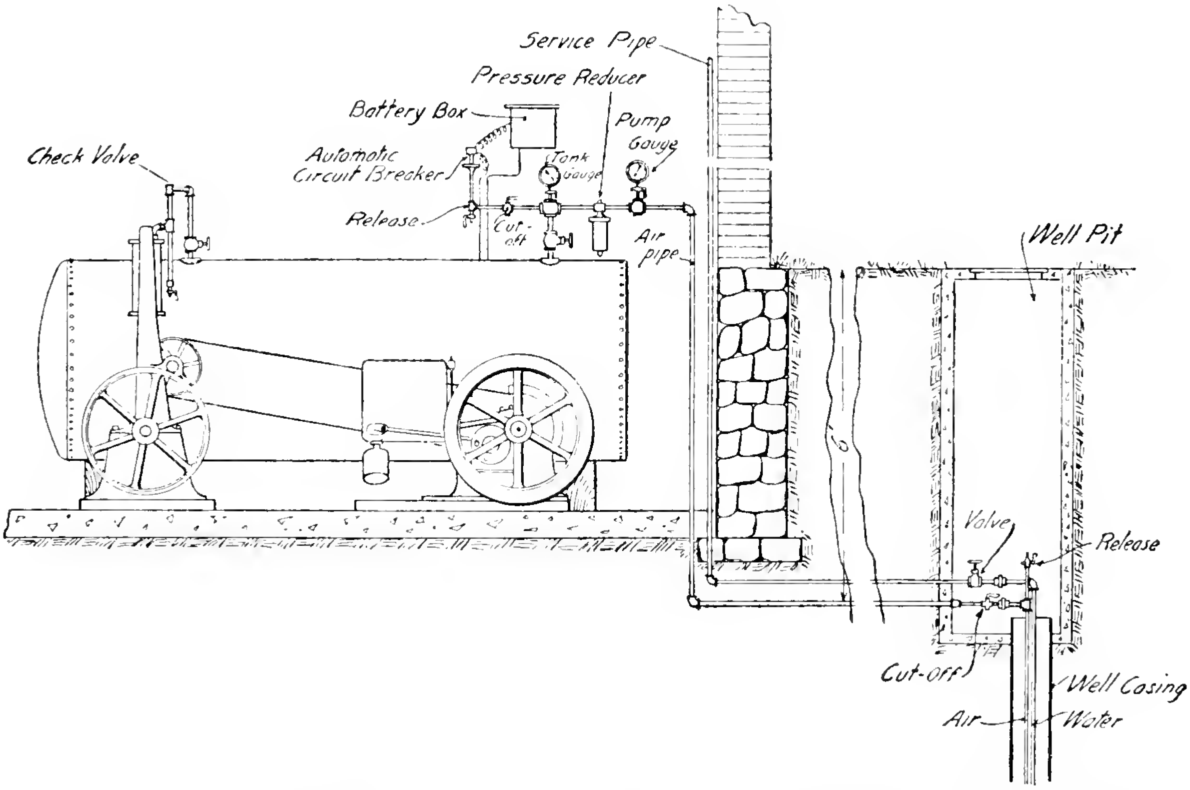

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FIG. 288. *The pneumatic system. This is aranged with a switch operated by air pressure to stop the engine when maximum pressure is reached.*

Pneumatic system. The pneumatic system (Fig. 288) consists of an engine or motor, air pump (compressor), air tank, reducing valve, and a special two-chambered pump (Fig. 289). This pump is placed in the well, under water. The compressed air is piped to it. Water may run into one chamber; when this is filled, a float opens the other chamber and allows the air to enter the filled chamber and force the water up the service pipe to the faucets. While one chamber fills, the other discharges. The automatically operated valves cause a continuous flow in the pipes. If all faucets are closed, no water can get out, so no air comes in. In this system the water is pumped direct from the well to the faucets. It is not stored.

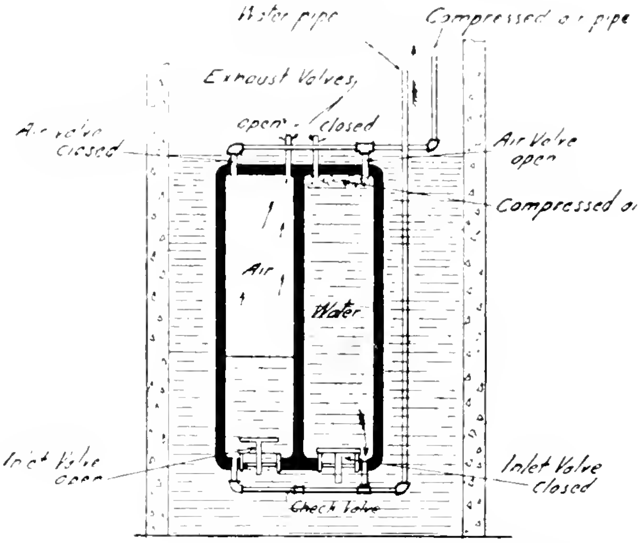

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FIG. 289. *Diagram of the operation of the special two-chamber pump. There are no pistons.*

The shortcomings of this system appear when several faucets are opened at one time, or when the pressure-regulating valve is opened to make it possible to do lawn sprinkling or buggy washing. When this is done, the air is allowed to enter the pump proper more rapidly than the water can enter. The action is so vigorous that the floats hook up, with the result that no water is delivered at the faucets. This system is a little more expensive than the hydropneumatic because of recent patents on the special pump.

Hydraulic ram. A ram is worth consideration where there is a good spring or creek, safe and clean, or a flowing well below which a little slope may be found, together with an oversupply of water. Figure 290, page 372, shows the parts and principles of the hydraulic ram. From a source, *G*, the water flows down a drive pipe, *A*, flowing out of the valve, *F*, until the friction of the passing water closes this valve. Then the oncoming column of water, *A*, pushing into the airchamber, *C*, compresses the air, passes out the service pipe, *D*, until the force of the water in *A* is balanced by the weight of water in *D*. *E* will now close of its own weight. *F*, likewise, will open, and the water in *A* will again start to flow and the process is repeated. This gives an irregular

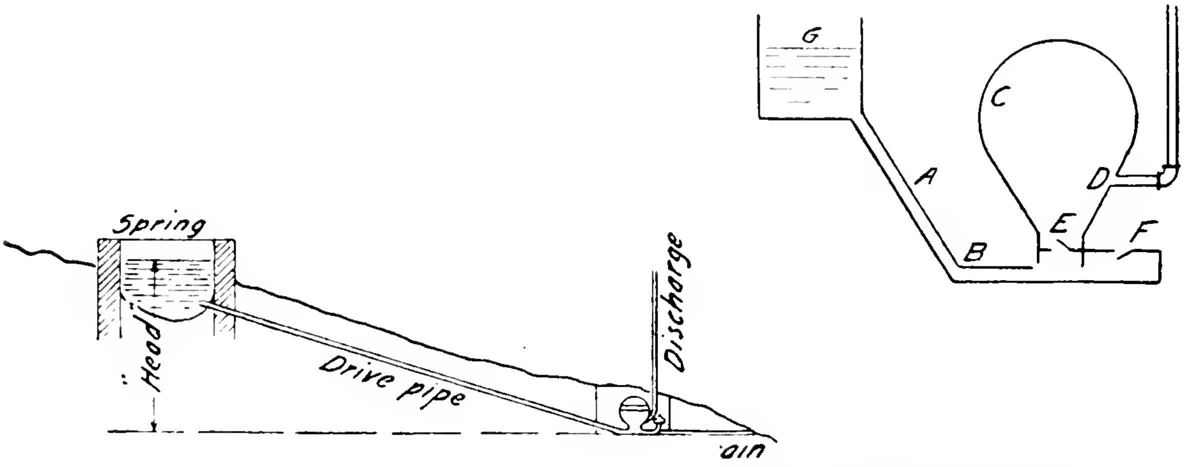

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FIG. 290. *Principle and method of installing a hydraulic ram*

flow, but is very reliable and not expensive. A 5-foot head will raise water 40 feet provided pipe *A* is 30 or 40 feet long. Only about one-seventh of the available water can be raised, but the ram will work night and day. One feature not to be overlooked in the installation of the ram is the provision for a spillway for the six-sevenths of the water supply which has been through the ram. If this is not provided, the ram will be submerged and cease to operate. A ram will cost from $11 to $24. Pipe and supply tanks are the large items.

Piping. All pipes offer a resistance to the flow of water through the pipes. This is influenced most largely by the diameter, length of the pipe, and the quantity of water to be forced through. It will be noted from the table at the top of page 273 that with the low head or pressure it will be necessary to use one-inch pipes in most cases.

Friction of Water in Pipes

FRICTION LOST IN POUNDS PRESSURE PER SQUARE INCH, FOR EACH 100 FEET OF LENGTH IN DIFFERENT SIZE CLEAN IRON PIPES, DISCHARGING GIVEN QUANTITIES PER MINUTE

Gallons per Minute	Sizes of Pipes in Inches—Inside Diameter								
	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	6
5	4	1							
10	13	4							
15	27	7							
20	46	12							
25		18	7						
30		25	9						
35		33	11						
40		42	15						
50			22	9					
60			31	13					
70			42	17					
80			52	22	6				
100				32	9				
120				47	12	4	2		
140					16	5			
160					20	7	3		
180					25	9			
200					31	10	4	1.3	0.2

Sizes, Weights, and Costs of Standard Iron Pipe

Diameter			Weight per Foot	Net Cost per 100 Feet	
Nominal Inside	Actual Outside	Actual Inside		Black	Galvanized
Inches	Inches	Inches	Pounds		
1/8	0.405	0.270	0.246	$1.77	$2.93
1/4	0.54	0.364	0.426	1.93	3.19
3/8	0.675	0.493	0.570	1.93	3.19
1/2	0.84	0.622	0.855	2.40	3.33
3/4	1.05	0.824	1.140	2.90	3.93
1	1.315	1.049	1.690	4.28	5.81
1 1/4	1.66	1.380	2.290	5.80	7.87
1 1/2	1.9	1.610	2.740	6.93	9.41
2	2.375	2.067	3.690	9.32	12.65
2 1/2	2.875	2.469	5.850	14.74	20.01
3	3.5	3.068	7.660	19.28	26.16
3 1/2	4.0	3.548	9.240	24.10	32.38
4	4.5	4.026	10.900	28.56	38.37
4 1/2	5.0	4.506	12.700	33.27	44.70
5	5.563	5.047	14.900	38.78	52.10
6	6.625	6.065	19.200	50.30	67.58

All water pipes should be galvanized. Where pipes are exposed at fixtures they are usually nickel-plated and supplied by the manufacturers. Underground pipes to the house and barns should be an inch in diameter; to the attic tank, three-quarters of an inch; to sill cocks, three-quarters of an inch; to hot-water tank, three-quarters of an inch; all others, one-half an inch. Vent pipes are of wrought iron. Soil pipes should be of cast iron. It is not now necessary to use lead pipes at any point. Cast-iron traps with pipe threads are to be had in all styles and will make a better job than ever was secured by the use of lead pipe and wiped joints.

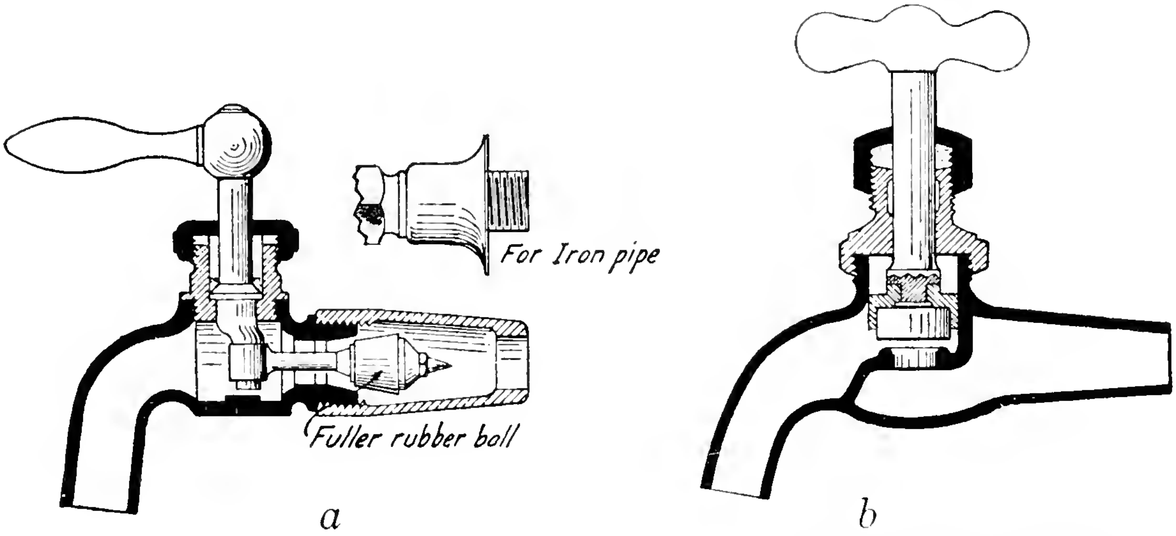

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FIG. 291. *Construction and operation of valves used at sinks. These are brass or nickel-plated.*

a—Cross section of fuller bibb (plain pattern for lead pipe)
b—Compression bibb (plain pattern for lead pipe)

Fittings for this work are called "drainage fittings" and are so made that the surface is smooth when the fittings are screwed tight. The soil pipe leading to the roof and to the closet should be of cast iron, 3 or 4 inches, extra heavy. Fittings are to be had to make connection between the screwed-joint waste pipe from the bath, lavatory, and sink and the cast iron of the soil pipe. The cast-iron soil pipe should extend beyond the foundation wall; thence to the conduit it may be of sewer pipe. The soil pipe to the roof affords ventilation to the system and prevents the breaking of the seal in the traps of other fixtures. It is not necessary to vent each fixture, as indicated in Figure 292, but this is an additional precaution against the syphoning of the traps, allowing for and equalizing the pressure on the two sides of other traps when one fixture is being flushed.

All horizontal runs should be given a little pitch to aid in draining. It is a good practice to place no pipes in outside walls on account of the damage from frost. A kitchen sink may be placed against an outside wall, and the water pipes placed inside the room, exposed. A heating plant is necessary before a water system is installed, in order that the house and cellar temperature may not go below the freezing point.

Fixtures. Fixtures should have a hard, smooth, impervious surface. The best the market affords are made of enameled iron, or porcelain on iron, and of clay. The last is too expensive except in the closet. Of the other two, the porcelain on iron is much more common and is known as the standard.

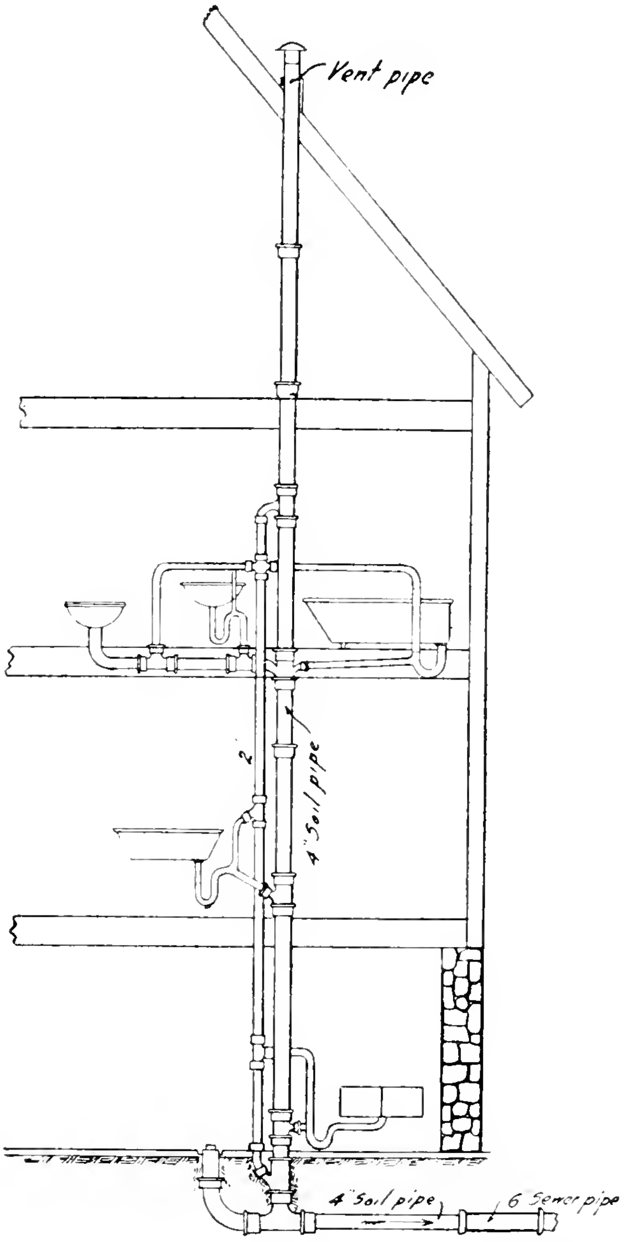

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FIG. 292. *Soil pipe, vent pipes, and trap for house installation*

For the kitchen a rolled-rim sink, with back, is good; but an objection is raised because of the difficulty found in placing work table and drain board up to it. A flat-rim sink is better in this respect, but has no back.

In buying a bath tub, it is well to get the long "army" legs. The solid tub, to be built in, is too expensive, and high legs make it much easier to sweep under the tub. Lavatories are of many styles. This fixture should have a rolled rim, with back, all in one piece.

Figure 297 shows the three types of closet. The washout uses a minimum of water, but does not flush so effectively as the other two. The small quantity of water allows the soil to come in contact with the surface of the closet, and the

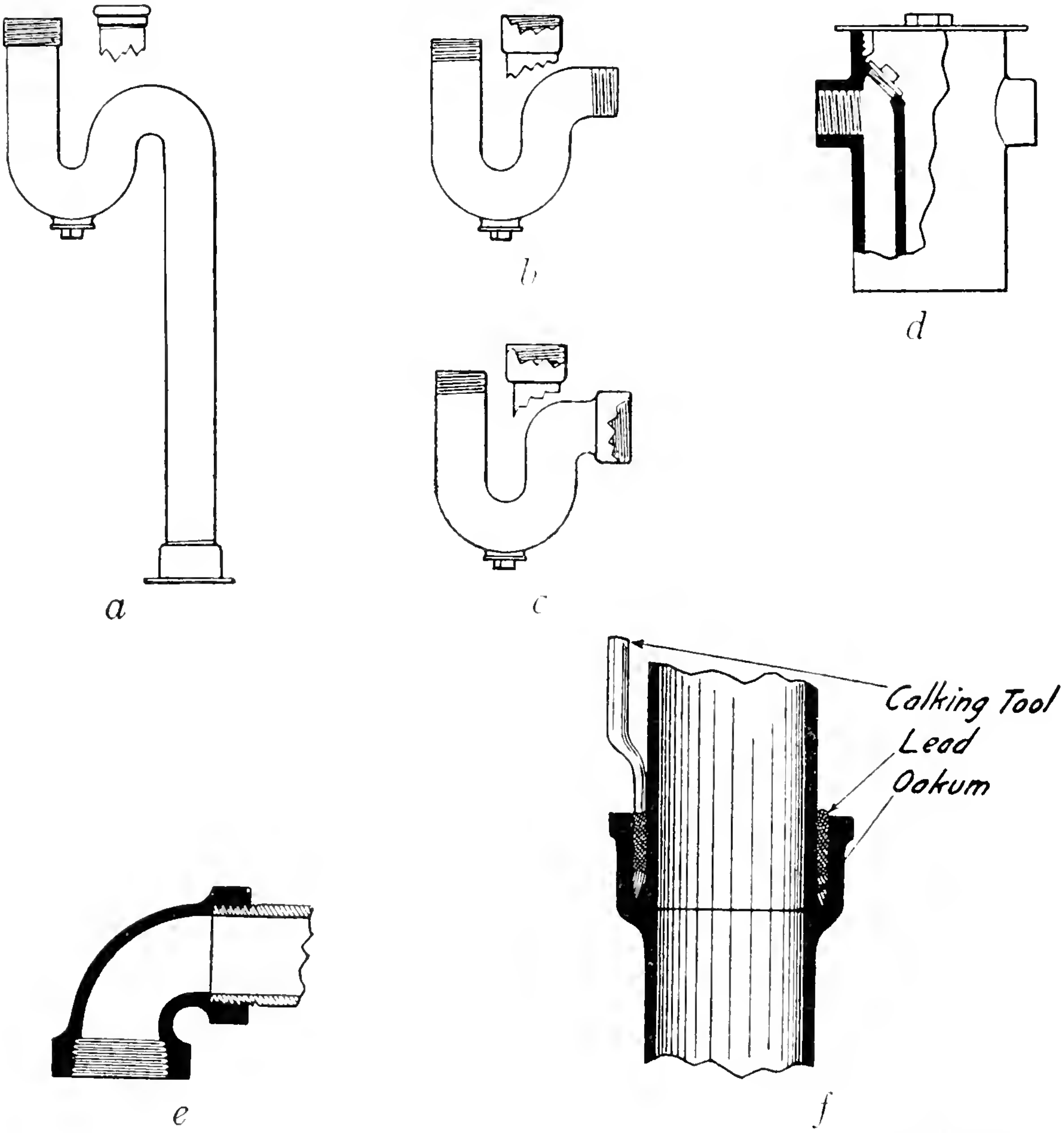

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FIG. 293. *Types of closets, cast-iron trap with iron pipe threads, known as drainage fittings. A calked joint in cast-iron soil pipe.*

a—Cast-iron trap, brass clean-out
b—Iron pipe threads
c—Cast-iron half "S" traps
d—Cast-iron drum trap
e—Drainage fitting screwed for wrought pipe
f—Calking vertical joint

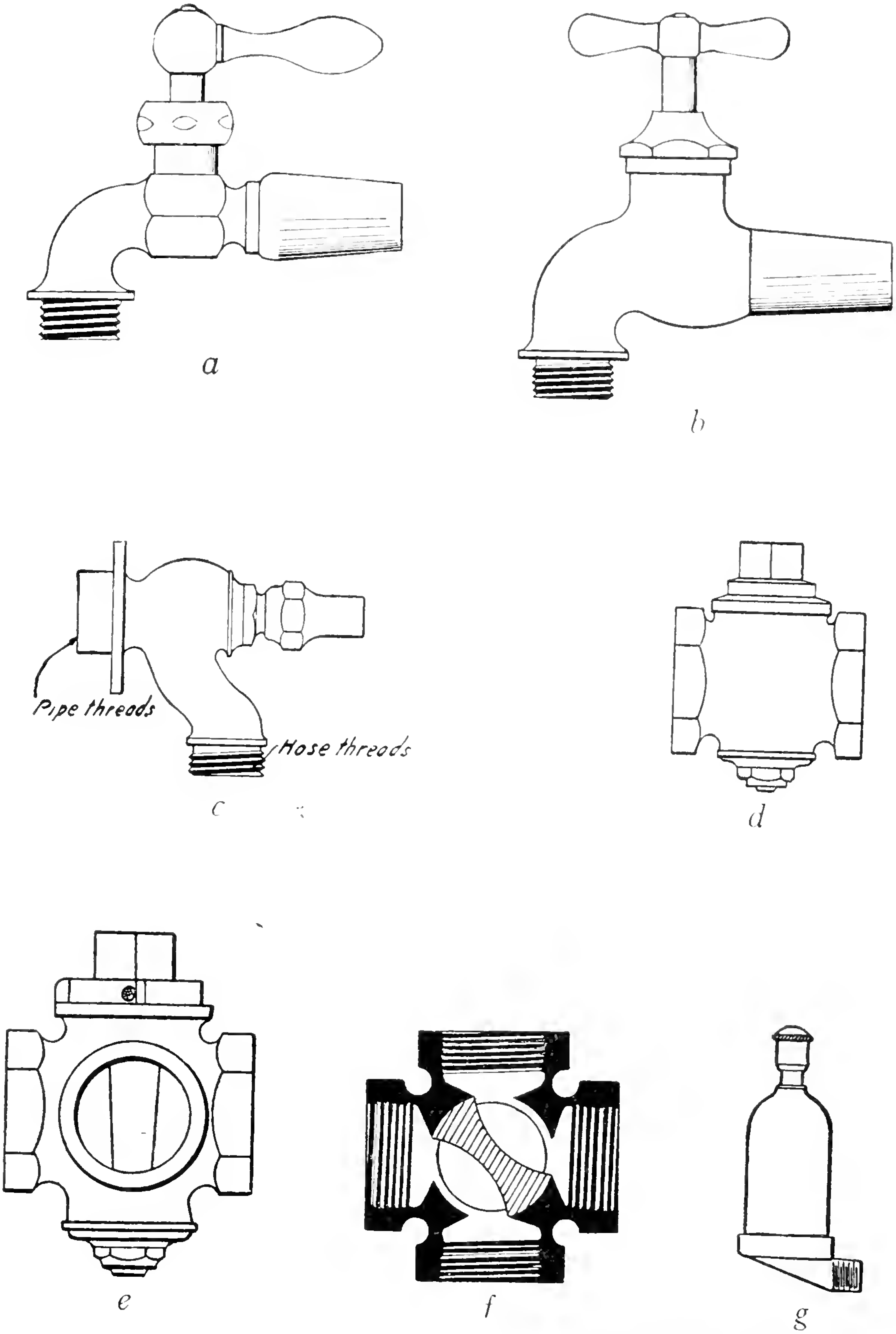

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FIG. 294. *Fittings used in ordinary installations of water systems*

a—Fuller hose bibb for lead pipe
b—Compression bibb for lead pipe
c—Still cock (loose key)
d—Cock
e—Three-way cock
f—Four-way cock
g—Automatic air valve

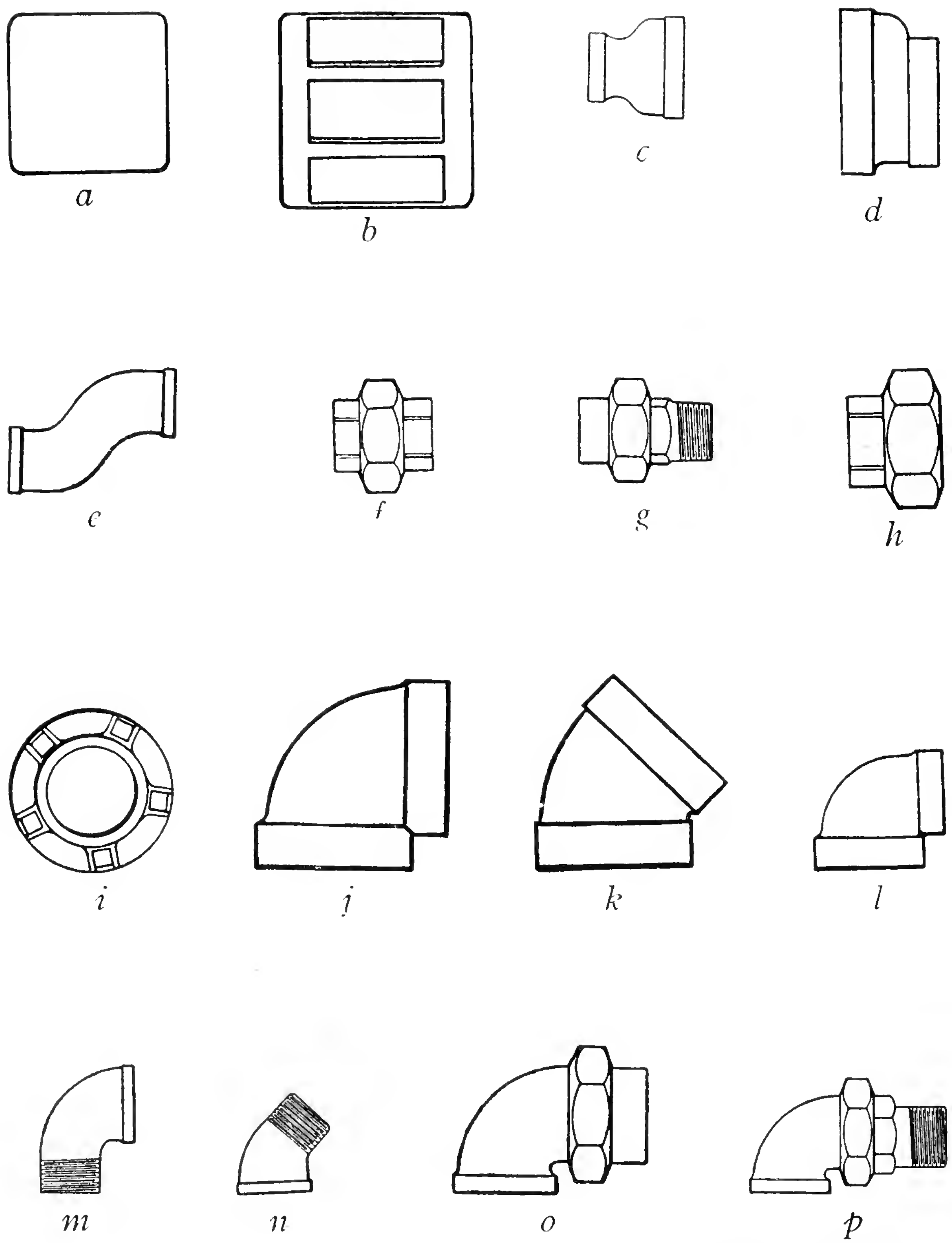

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FIG. 295. *Fittings used in ordinary installations of water systems*

a—Wrought-iron coupling
b—Malleable iron coupling, ribbed right and left
c—Malleable iron reducer
d—Cast-iron eccentric reducer
e—Malleable iron offset
f—Malleable iron union
g—Male and female union
h—Two-third union
i—Flange union
j—Cast-iron elbow
k—45° cast-iron elbow
l—Cast-iron reducing elbow
m—Malleable iron street elbow
n—45° street elbow
o—Female union elbow, malleable iron
p—Male union elbow, malleable iron

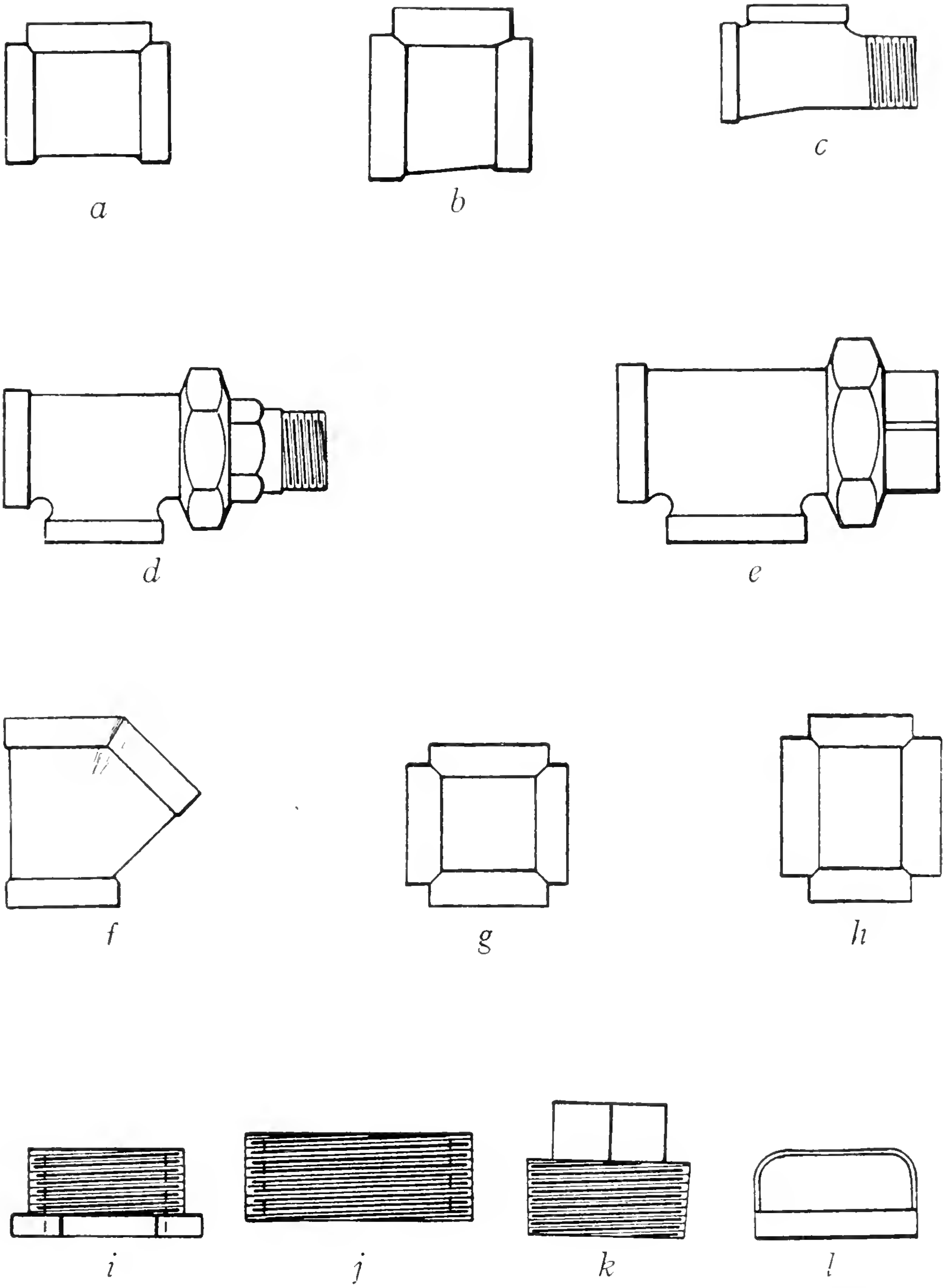

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FIG. 296. *Fittings used in ordinary installations of of water systems*

a—Straight tee, cast iron
b—Reducing tee, cast iron
c—Service or street tee, malleable iron
d—Union tee (male), malleable iron
e—Union tee (female), malleable iron
f—Cast-iron Y bend
g—Cast-iron straight cross
h—Cast-iron reducing cross
i—Cast-iron bushing
j—Faced bushing
k—Cast-iron plug
l—Malleable iron cap

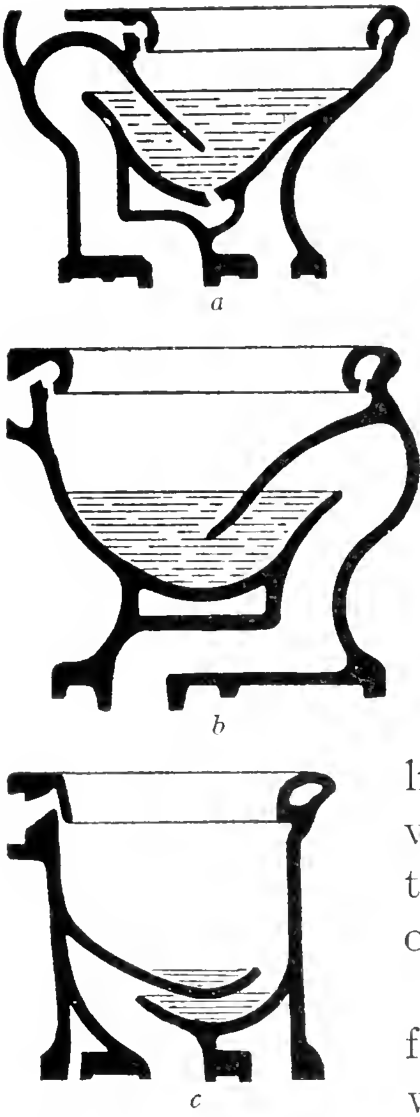

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FIG. 297. *Types of closets*

a—Syphon jet closet
b—Syphon-action closet
c—Washout closet

flush is often not sufficient to cleanse. The syphon jet is very effective, but has a small passage, which will in time scale up from the action of the water, making the flush very poor. The syphon-action wash-down type is the popular one. Though not so quiet in operation, it always works.

Laundry tubs are made with two or three chambers, the two-chamber tubs being most common. They are made of concrete and of Alberine stone. The cost of these is the same. Tubs should be placed where there is good light. A floor drain in the laundry is very convenient, but care must be taken to pour a pail of water through it often to keep the trap full.

Figure 298 shows the proper connection for a hot-water back in a range or to a water coil in a heating plant. It must be remembered that all water, especially that from wells, contains a great deal of mineral matter. Such waters are known as hard waters. When the water is heated, nearly all of this mineral matter is deposited in the form of scale on the heated surfaces. This deposit takes place while the water is at a temperature somewhat below boiling. Therefore the heating coils and water backs, used for heating water, in connection with a

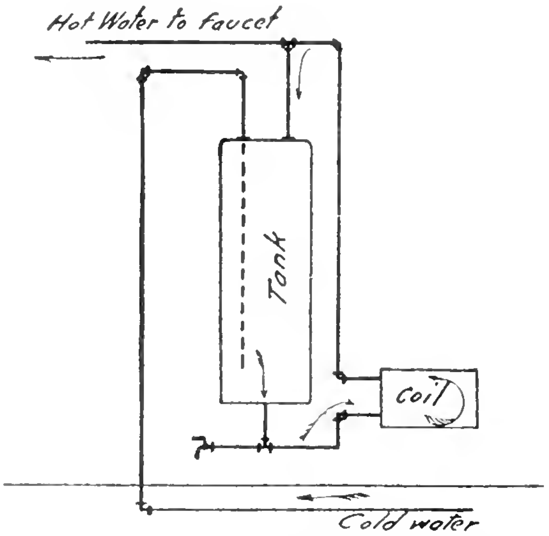

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FIG. 298. *Connection of a hot-water tank with a kitchen range or furnace*

tank, are certain to fill in time. The filling usually makes itself evident by a gradual lessening supply of warm water. In the case of a water back such as is used in a kitchen range, an explosion is occasionally produced because the pipes

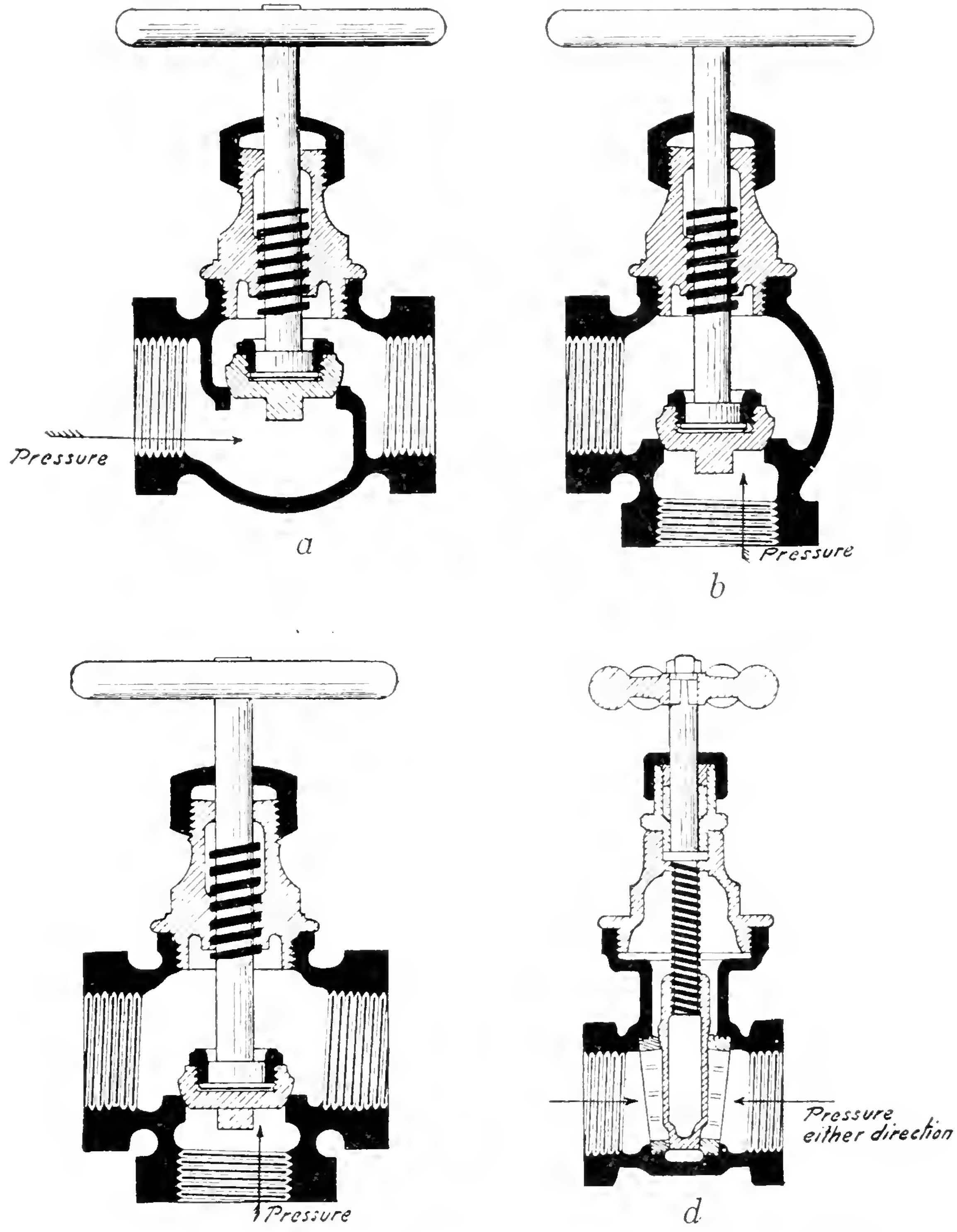

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FIG. 299. *General construction of globe and gate valves and proper way to place them*

a—Globe valve
b—Angle valve
c—Cross valve
d—Straightway or gate valve

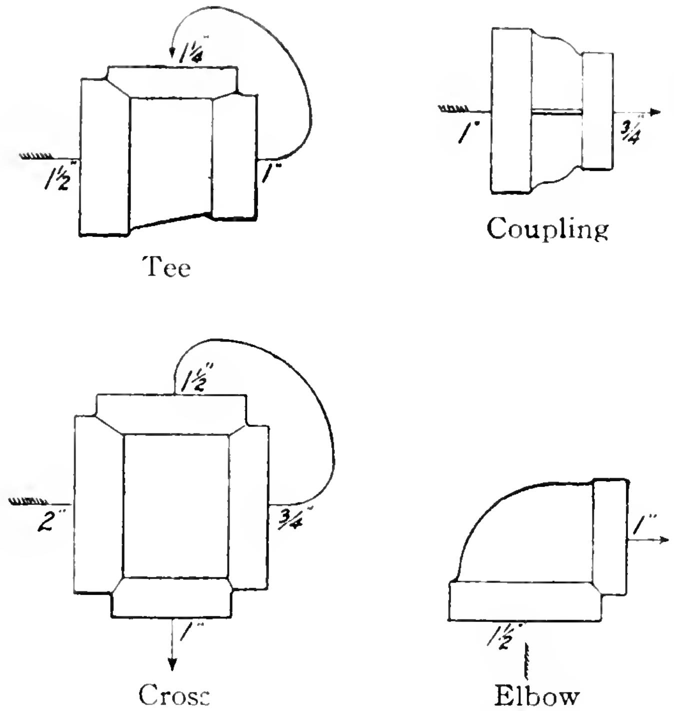

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FIG. 300. *Reading reducing fittings. Read straight through as indicated by arrows, as Tee* 1½×1×1¼; *cross* 2×¾×1½×1; *coupling* 1×¾; *elbow* 1½×1

leading to and from the water back have filled and the expansion in the water chamber is more than the metal of this member can stand. There is no remedy for this depositing. It is simply a case of replacing the plugged parts when they become filled.

The table on page 373 gives the dimensions, weight, and cost of standard black iron and galvanized-iron pipe usually carried in stock

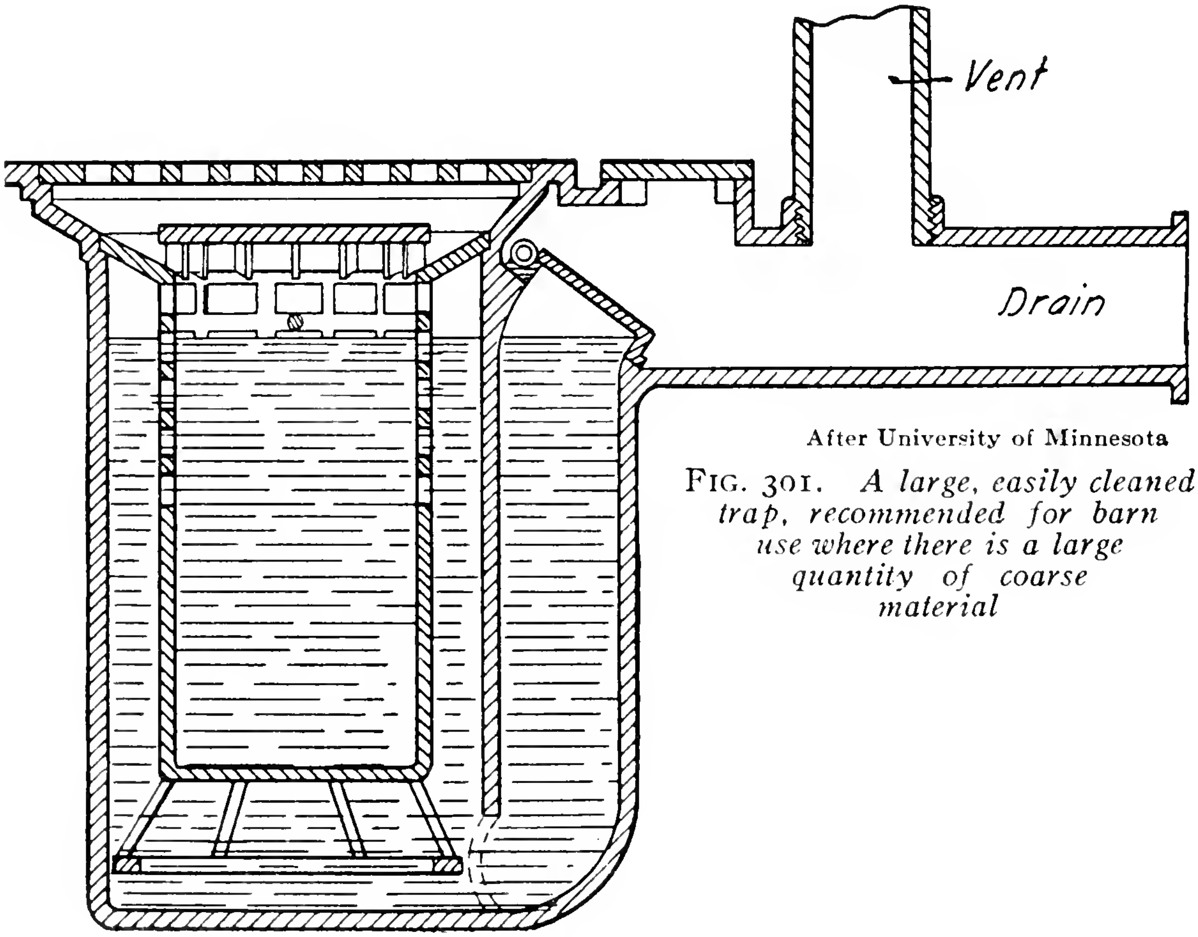

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FIG. 301. *A large, easily cleaned trap, recommended for barn use where there is a large quantity of coarse material*

by dealers, up to 6 inches in diameter. The net cost per hundred feet, as shown in the last column, was the ordinary retail price in July, 1914. These prices will vary in different towns on the same date and are subject to change owing to the market prices of iron or steel. However, these prices are comparative between black and galvanized pipe and between the various sizes and can be used for estimating when the local market prices of only one or two sizes is known.

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CHAPTER XVIII

SANITATION

Sanitary methods that have been tried and are known to be absolutely safe in the larger communities are often too expensive and impractical for isolated houses; while methods that might be adequate, from the standpoint of sanitation, in the individual house would not be satisfactory if applied to several houses or to a large number of persons in one building.

Science has been able to identify the germs of many fevers and other diseases and to prevent their spread by proper sanitary measures. As a result, disease germs are now eradicated which a century ago would have caused a widespread pestilence resulting in great economic loss as well as suffering and death. These preventive measures were first applied to the cities; but it has been thoroughly demonstrated that sanitary measures are of as great advantage, proportionately, to the rural districts as to localities where large numbers of people congregate.

There is great need of using proper methods around the farmstead for the drainage of all wet places, for the protection of drinking water, and for the sanitary disposal of all the waste, slop, and filth which ordinarily accumulate around human habitations. What is true of man also applies to a large extent to the lower animals; measures that benefit one benefit the other.

The subject of sanitation can be divided roughly into two parts: one, the protection of the household water supply, that it may be kept free from disease germs; and the other, the disposal of all waste and filth in such a manner that the disease germs cannot be taken up by flies or animals, or leached out by the water and transmitted directly or indirectly to residents of the locality. The protection of the water supply is discussed in chapter xvii in direct connection with the location and construction of wells; in this chapter the second phase of the problem only will be considered.

Drainage. One of the first requirements of the farmstead is the thorough underdrainage of the land to be used for yards, gardens, and building purposes. These drains should be laid from 3 to 5 feet deep. They should extend around the foundation of the house, at least a foot below the bottom of the cellar, one line beginning near the well. Low places where water is likely to stand after a rain should be either filled or underlaid with a drain. It is also desirable, whenever practicable, to connect all downspouts from roofs directly with the underdrains. If this is done, breeding places for water insects are destroyed, water is kept out of the cellar, unpleasant odors are prevented, and the general sanitary conditions of the premises are aided if the ground is kept dry.

In draining the farmstead, it should be remembered that where the surface is thoroughly tramped by stock it becomes impervious to water, and there is no downward flow of surface water. Consequently direct inlets should be made into the tile in the vicinity of wells and other places that are exposed to severe tramping. In ordinary soils water readily finds its way to underdrains from lawns and cultivated lands.

Incinerators. If neglected, much material that is not only valueless, but unsightly and unhealthful, will collect about a farm. One of the best means of disposing of such material is by fire, and a safe place for burning worthless accumulations should be located near the buildings.

A small *incinerator* for this purpose can be cheaply built of hard brick (Fig. 302), concrete, or, what is just as good, an 8-foot length of an old smoke stack, not less than 2 feet in diameter. At the bottom of this incinerator there should be a sufficient opening left for draft. The refuse is thrown in at the top, and when the receptacle is full, or begins to become offensive, kindling can be placed in the draft opening and the fire started. With the addition of a small quantity of wood, the entire mass can be burned out in two hours, after which the incinerator is ready for refilling.

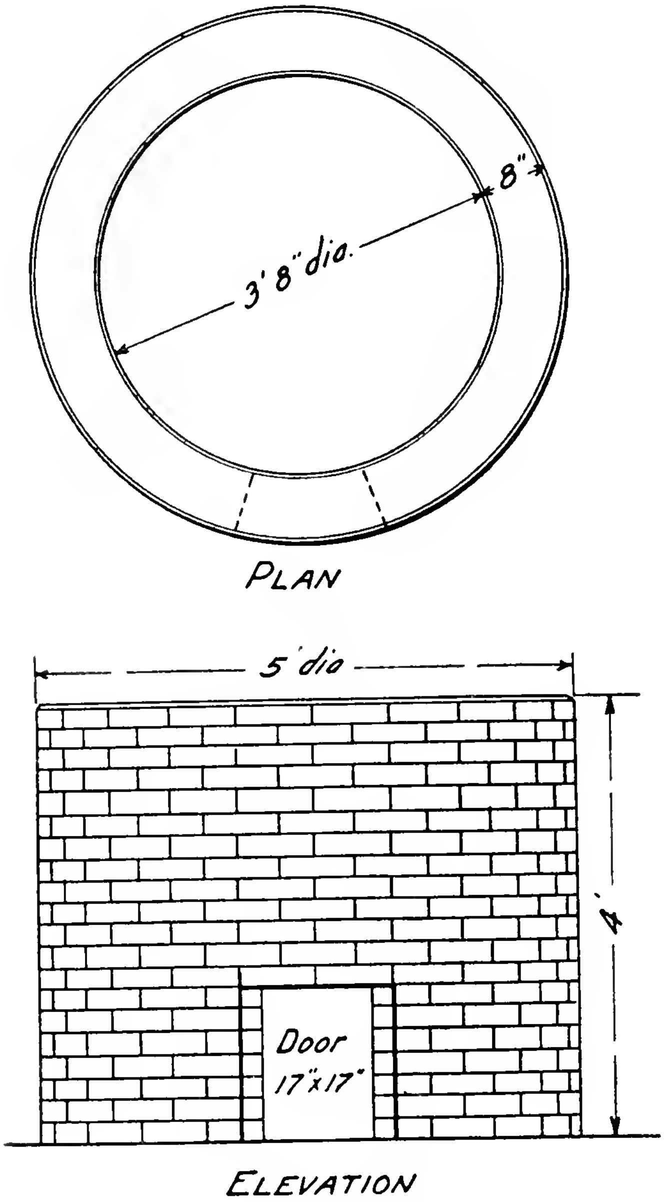

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FIG. 302. *Plan and section of an incinerator, constructed of hard-burned brick laid up in cement mortar. It was erected within 50 feet of the kitchen door, and burned all solid refuse from a kitchen where 250 men were boarded, the only fuel used being the paper and packing boxes that came with supplies.*

Into this crematory should be thrown all waste papers, worthless pieces of wood, old clothing, bones, poultry feathers, bodies of poultry and small animals, and any other worthless refuse that will burn. Only a small quantity of fuel is required to be mixed with this material to cause it to burn. While the receptacle is being filled with refuse, the draft opening and the top should be protected by a light covering of sheet iron or wood.

It is advisable that all tin cans and bottles as soon as emptied be thrown into the incinerator. Cans, when first emptied of their contents, usually have adhering to their walls a large quantity of juice or other material that will attract flies. After a rain the cans will be partially filled with water and afford an excellent breeding place for mosquitoes. Later on, the paper wrappers on the outside decay and become unsightly. If the can is exposed a few minutes to a hot fire, the paper covering and all of the inside contents are burned, the soldered joints melted, and the can, when thrown out on the ground, quickly rusts and disappears.

Animals which have died from disease should, if possible, be burned or buried, and not left to decay on the surface. The burning removes an unsightly object and destroys all disease germs. Fire should be used more generally than at present for the destruction of unsightly material around the average farm dwelling.

The disposal of excreta. One of the most difficult problems to solve in sanitation is the disposal of human excreta. The methods ordinarily adopted in newly settled communities cannot be too severely condemned, although, under existing conditions, in many localities it is impossible to remedy this trouble.

Two different methods of treatment have been suggested. In one some foreign material, such as fine earth, peat powder, or air-slacked lime, is mixed with the excreta in sufficient quantities to cause rapid disintegration, when it can be removed. This is usually known as the dry method. The other is to use a liquid containing chemicals. This dissolves all solid matter placed in it. The harmless liquid is then easily disposed of. This is known as the wet method. Neither of these methods is entirely satisfactory, for the reason that the receptacles become offensive if they are not given proper attention, and the attention required to make either method successful is more than can be expected to be given under ordinary farm conditions.

For further information on the subject of a sanitary outbuilding, the reader is referred to *Farmers' Bulletin 463*, United States Department of Agriculture, Washington, D. C.

With modern plumbing inside the dwelling there is an increased demand for some method of disposal similar to that furnished by the sewer in the city. For convenience, comfort, and general sanitation the modern bathroom and toilet fixtures are recommended, and should be installed wherever possible; but, in order to make a modern bathroom sanitary, some efficient method is necessary for the disposal of all waste which is carried by liquids from the house.

Cesspool. A common practice has been to drain this waste into a pit or cesspool near the house, a cesspool being an opening in the ground, either curbed with lumber or walled with brick. If the soil is porous and permits the water to percolate with fair rapidity, the liquid drains out, and the solid matter left will fill up the pool. If the soil is impervious, the liquid will not escape as rapidly as it accumulates, and in a short time will be flowing over the surface. Many cesspools which work satisfactorily for a few months or two or three years finally fail to work, and overflow because of the clogging of the soil by the solid matter held in solution. When this occurs, it is necessary to construct a new cesspool. The cesspool saturates the surrounding ground for a long distance with disease germs, which in time may be carried into the house water supply. However, reports come in occasionally regarding cesspools which have worked for several years, and to all appearances were perfectly satisfactory. If such a pool is examined, it will be found that the conditions are somewhat unusual. The porosity of the earth a short distance below the surface is such that the liquids escape at approximately the same rate as they enter, the lower part of the pool being practically impervious. Consequently the liquids are held at a uniform depth. This condition of the pool, combined with other conditions, favors the growth of certain bacteria carried in house sewage. These bacteria, working in the sewage, cause all the solid matter to be separated into liquids and gases. The gas escapes into the air and the liquid disappears in the soil. The cesspool, owing to favorable conditions, is acting as a septic tank and gives satisfactory results.

Septic tanks. It has been found that, if sewage can be held for a given length of time under proper regulations of light, heat, air, and current, the solid matter will be decomposed and the waste from a septic tank will be much less dangerous and objectionable than from a cesspool. As the natural conditions for the proper working of a cesspool as a septic tank seldom occur, it is desirable in the beginning to construct a tank in such a manner that the bacterial growth will be promoted. These bacteria thrive best where there are a limited amount of light and air, a certain degree of heat, and a surface unbroken by flowing water. These conditions are secured by the discharge of the sewage into a tank from which the light is excluded by a covering, air being admitted through a small vent. Heat is supplied by the

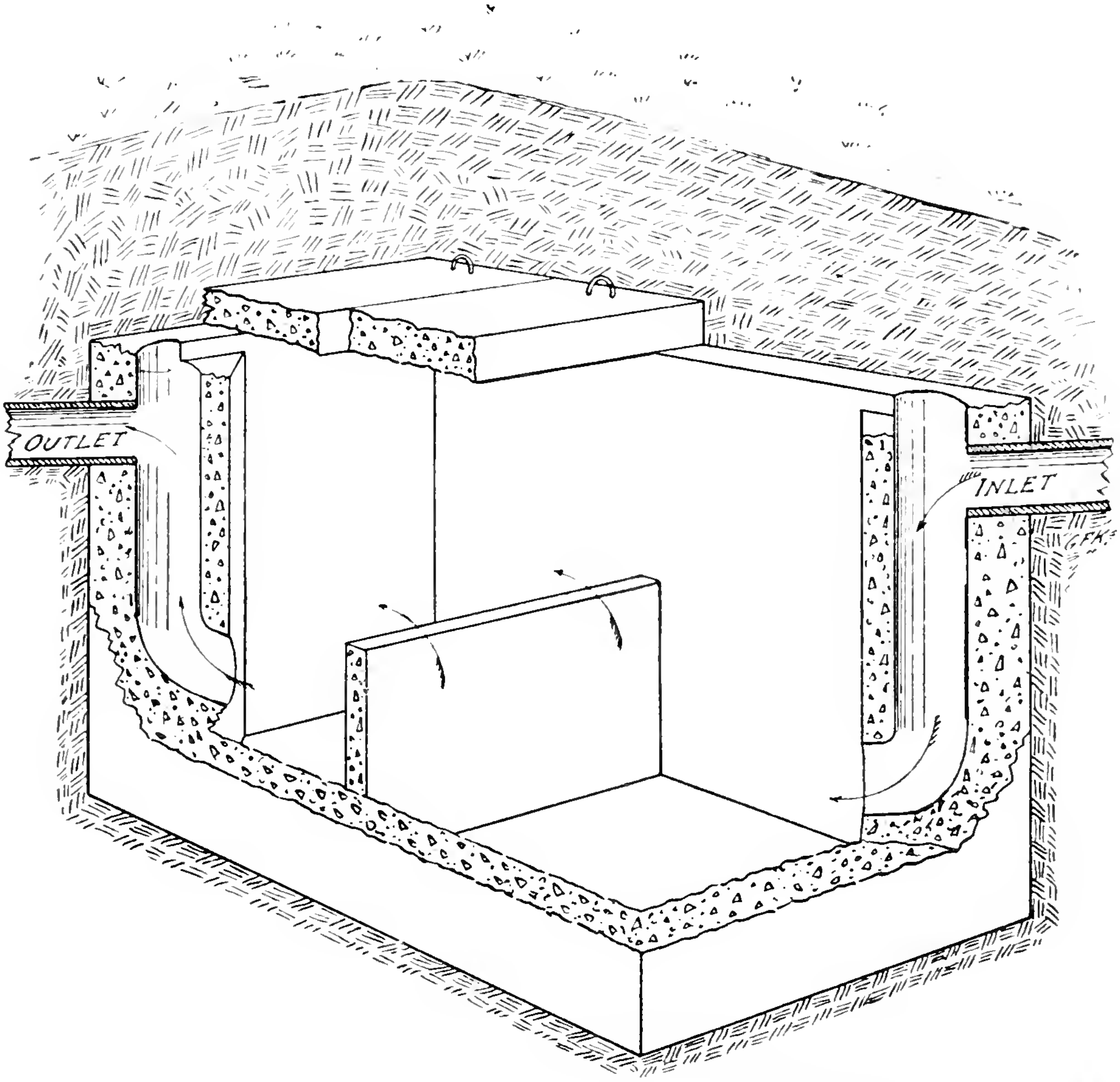

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FIG. 303. *General view of a septic tank*

water used in the sinks and lavatories, and possibly some heat is generated by chemical action in the tank itself. This heat is conserved by having the tank partially or entirely buried in the earth. Currents are prevented in the surface of the sewage by baffles or partitions through the tank, the sewage passing from one chamber to another through submerged openings. The solid matter is thus decomposed into liquids and gases, the gases passing off into the air, and the liquid, which is free from dangerous germs, being either discharged through a filter out upon the soil or carried away by ordinary drains to an outlet ditch. This waste material is thus deprived of its dangerous and unsanitary qualities by a system that is simple and requires but little attention after it has once been installed. Such systems, varying in their detail to meet local conditions, are now in use in many places throughout the country, and their operation is no longer an experiment.

Disposal of effluent. In the construction of a septic tank it is necessary that some provision be made for the final disposal of the liquid or effluent, for no liquid whatever is destroyed in the tank; it must all flow away. Three different methods of disposal have been used for the individual house tank. The first and most simple method is the direct discharge of the effluent from the tank into an ordinary farm drain tile. A 4-inch tile should be used where the grade is not less than 1½ inches to 100 feet. If less, a 5-inch tile will make a satisfactory outlet. Tile drains which have served as septic-tank outlets for five years or more, on flat grades, show no filling or sedimentation due to their serving as such an outlet. A drain of this nature carries the effluent of the tank from the premises underground, and finally disposes of it in some outlet ditch, where it is completely removed by the storm waters after heavy rains.

Open ditch. Where the liquid from a septic tank is carried a short distance by the tile and discharged into a shallow ditch, there is some trouble experienced in the wintertime by the liquid freezing in the ditch, thus closing the outlet. It is therefore desirable to get an outlet in as favorable a location as possible; if there is not plenty of room for the liquid to flow out and freeze without backing into the tile, it is well to cover the outlet with straw or coarse manure. Where the outlet is in a ditch that drifts full of snow no difficulty is experienced from freezing, as the liquid will disappear under the snow. Ordinarily no trouble has been experienced from freezing in the tile until it has frozen up in the open ditch and the ice has become so high that the liquid cannot flow. After that the liquid backs into the tile and freezes. While the sanitary condition of the effluent discharged in the final outlet is not so good as that discharged when either of the other methods hereafter described is used, it ordinarily will not become a nuisance around the outlet, even though the outlet ditch is dry part of the season, unless the tank is worked beyond its limit or there is a number of tanks outletting at one point. A small tank discharged for six years, through an outlet of this kind, into an open ditch only 300 feet from a residence alongside a public road and did not become a nuisance.

Absorption method. The second method is known as the absorption method. In this method the liquid is carried from the tank through a drain with water-tight joints, until it reaches a distribution system which consists of tile laid with open joints, such that the liquid can pass through and be absorbed by the soil. The more open and porous the soil, the more satisfactory is this method of disposal. A very compact, tight soil which does not permit water to pass through it readily, or a soil that becomes saturated with water during rainy periods, would not be a satisfactory one for this system.

The absorption system, shown in Figure 304, can be located at any desirable distance from the tank. There necessarily must be fall enough so that the liquid will readily flow from the tank to the system. The tile should be laid practically level, and, since the air is of great assistance in purifying liquids, should not be over 10 or 12 inches deep. The liquid should reach the distributors in intermittent discharges, so that it will fill the entire system to the same depth in a short space of time. The flow of liquid should then cease, and the distributors will empty themselves by absorption into the soil. They should then stand a short time before being refilled. For the private house a discharge from the tank approximately once in twenty-four hours is satisfactory.

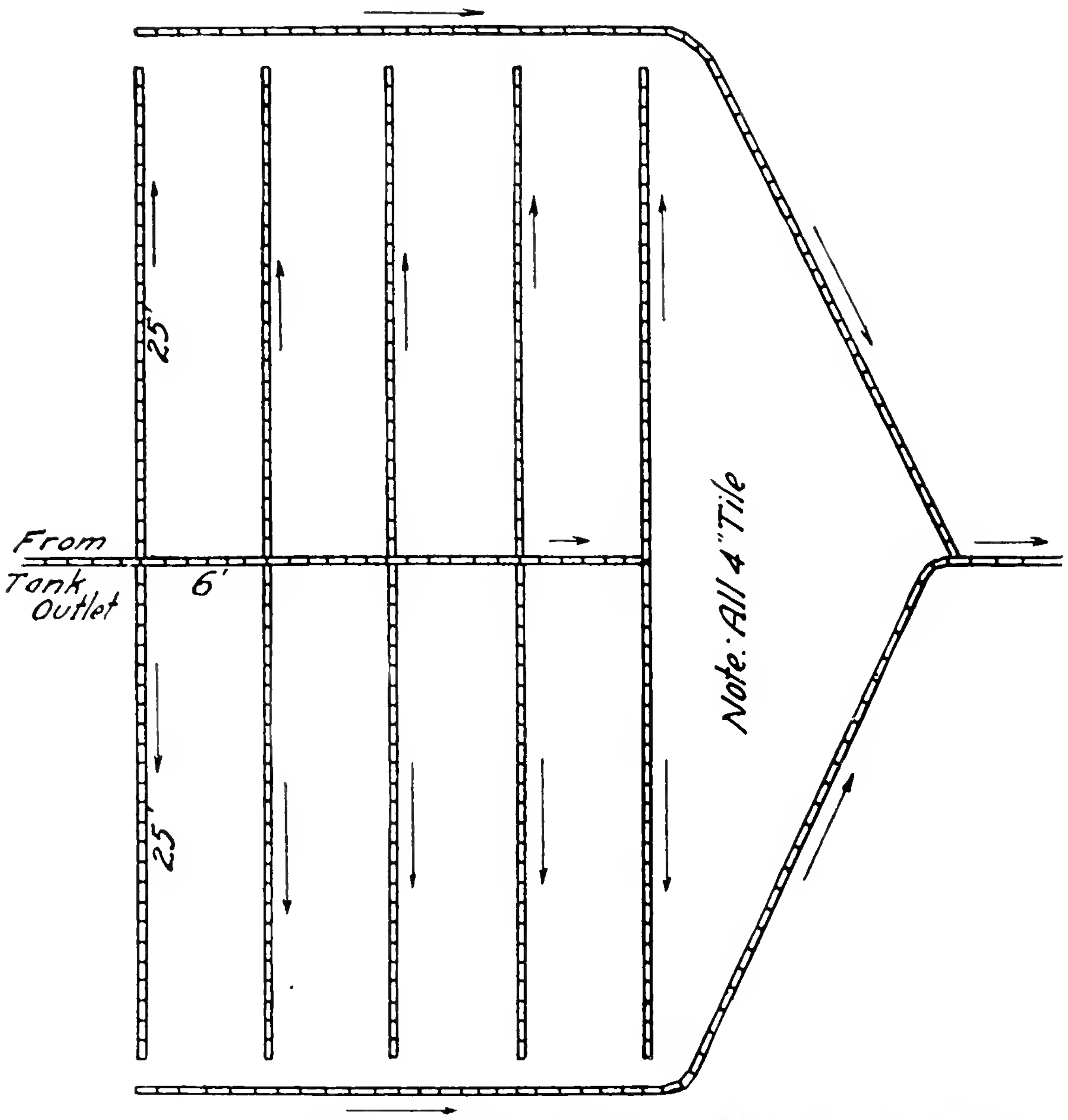

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FIG. 304. *Arrangement of open-jointed tile for an absorption system, with the addition of a drainage system laid around the outside*

The distributing drains can best be made from ordinary 4-inch drain tile. Since such a tile holds approximately one-half gallon per foot, the number of tile needed in the system can be determined from the size of the discharge chamber in the tank. It is best to make the total contents of the distributing system about 10 per cent larger than the total contents of the discharging chamber. Where there is a satisfactory outlet, or the fall is sufficient, a drain tile laid about 30 inches deep around the distributing drains, as shown in the figure, is very desirable, although not necessary. Such a drain will prevent the soil from becoming saturated at times of heavy rains. Where the absorption method is used for disposal, it is necessary to have an additional chamber in the tank for holding the liquid the proper length of time. Such a chamber should be large enough to hold all the liquid for approximately 24 hours, and discharge it at the proper time in a short period. This chamber must be fitted with a siphon or an automatic valve. Such valves are carried in stock by dealers in plumbing supplies and cost from $10 to $25 each. The discharge from the septic chamber of the tank into the discharge chamber should be carefully protected to prevent any coarse material which will clog the valves and prevent their operation from flowing through. The fact that these valves often get out of order and cease to work is one of the objections to this method of disposal, but, with care in construction and by the use of a good valve, they will give satisfactory results.

Filtration method. The third method is by the use of a filter attached to the discharge end of the tank and is not considered practicable for the ordinary farmhouse.

Form of septic tank. The form of septic tank is not material, so long as the conditions favorable for septic action are maintained. Light should be reduced to a minimum. A small quantity of air passing through the outlet of the tank, over the top of the liquid in the tank, and up through the inlet and soil pipe of the house is beneficial rather than detrimental. If the inlet or outlet of the tank is submerged so that there cannot be a free passage of air, a small air vent should be left in the top of the tank. Figure 305 shows the general arrangement of the outlet and inlet with the house and soil pipe. The tank must be sufficiently protected from the weather to prevent the temperature from going below 50° or 60° Fahrenheit. In Minnesota it has been found that 2 feet of earth over the top of the tank is ample protection for the winter months.

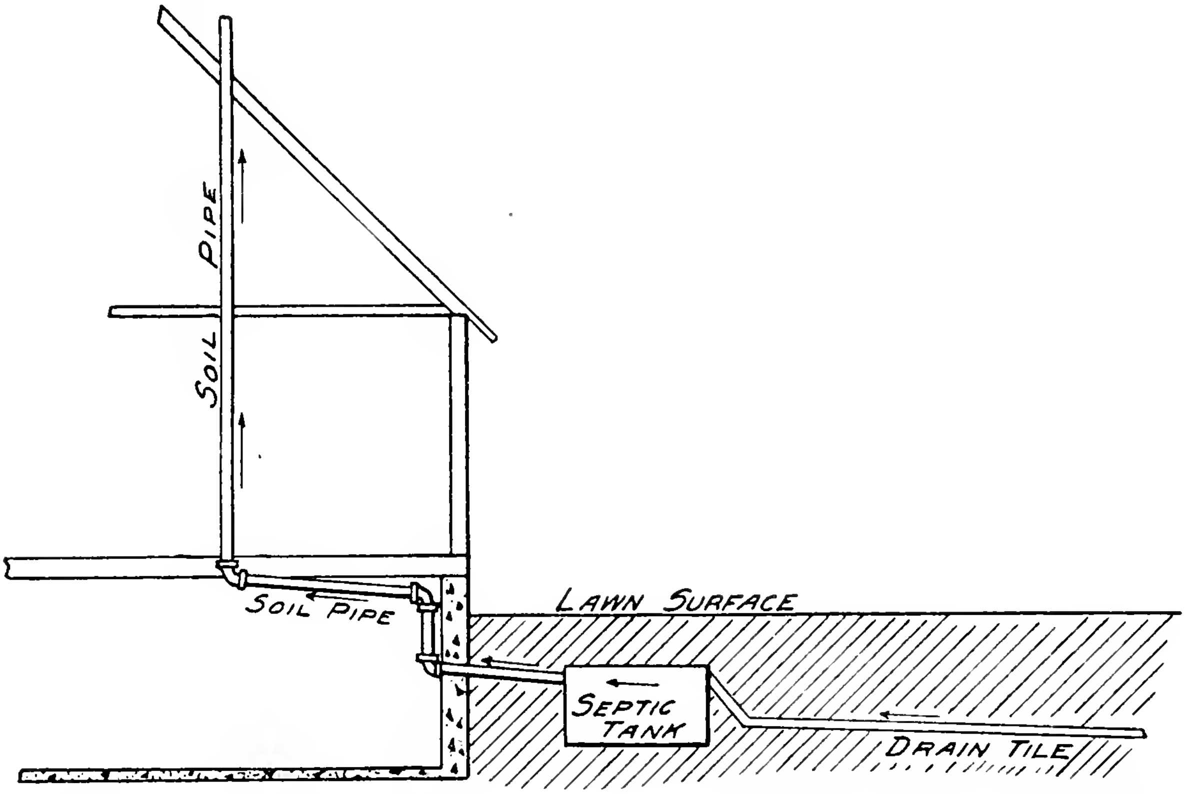

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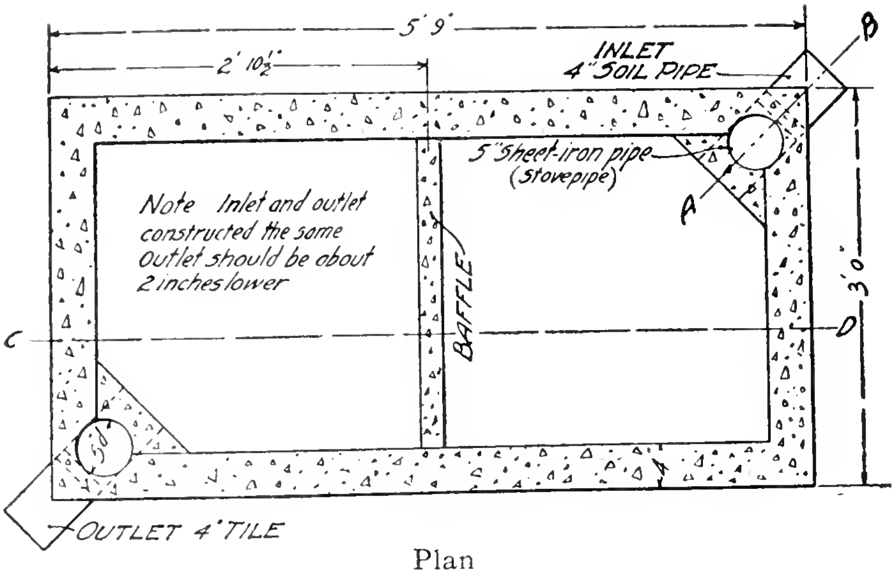
FIG. 305. *General arrangement of tile drain, septic tank, foundation of house, and soil pipe through house. Air circulation is indicated by arrow.*

It is very important that the inlet and outlet be so arranged that there can be no movement on the surface of the liquids, for the bacterial action takes place in the scum which accumulates and floats on the surface. If currents of water strike this, the scum is broken and a movement caused which prevents the proper bacterial action. The flow of sewage through the tank must be regulated by partitions or baffles. These can be made of any material or in any style desired, so long as they accomplish the purpose of breaking up all horizontal motion on the surface of the liquid.

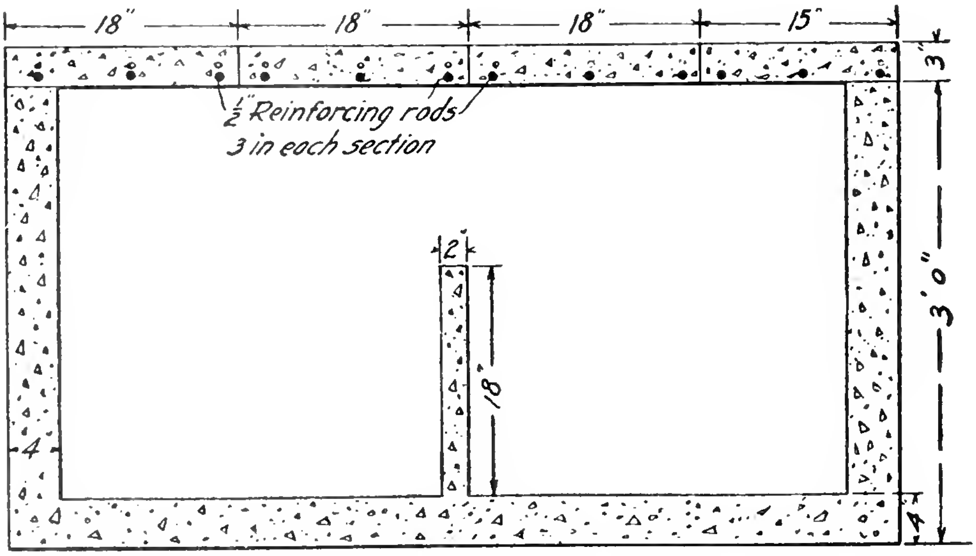
Figure 306 is a single-chamber tank that has been used where there is a tile outlet. This tank has been used for several years and is satisfactory. The number of chambers in the tank is dependent on the quantity of liquid flowing through the tank, and also to some extent on the nature of the liquid. From creameries and separator rooms, where there is a large quantity of liquid and a comparatively small quantity of waste matter to be destroyed, better control of the current can be had by use of a tank with several chambers, but for disposal of the sewage from an ordinary dwelling a single-chamber tank, properly constructed, is satisfactory—unless the method of disposal of the effluent requires an additional chamber.

Size of the septic tank. The size of the tank depends on the quantity of the liquid to be handled in a given length of time. Various authorities differ in regard to the length of time that the sewage should remain in the tank, this period varying from ten to thirty-six hours. For ordinary house sewage twenty-four hours are sufficient. The first chamber in the tank should be large enough to hold all the liquids which will be deposited in it for a period of that length. The quantity of water used per person varies from 20 to 100 gallons per day. This includes laundry, washroom, toilet room, etc. In the individual dwelling located in the country or small town 30 gallons per person per twenty-four hours are sufficient. Consequently the number of persons multiplied by 30 will give the size of the receiving chamber in gallons. This divided by 7½ will give the size in cubic feet.

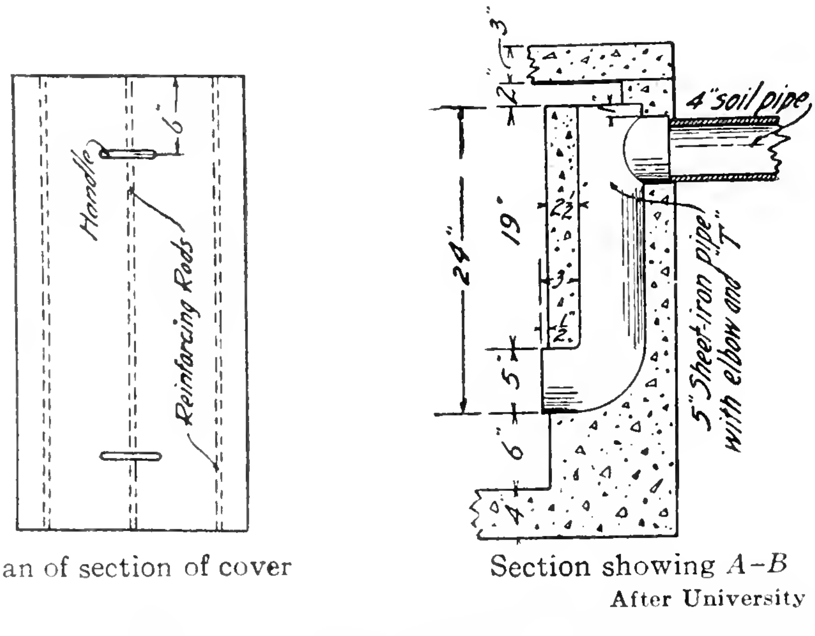
Location of the tank. Unless it is necessary to use a filter in connection with the tank, it is better to place the tank close to the foundation of the house. The sewage can then be discharged into it direct from the cast-iron soil pipe. If it is placed some distance from the house, it is necessary to carry the sewage through pipes that have water-tight joints, to prevent its leakage into the soil. In cold weather the liquid will lose some of its heat in passing through this pipe,



Plan



Cross section trench *C–D*



Plan of section of cover

Section showing *A–B*

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FIG. 306. *Details of a concrete septic tank connected to a drain tile*

and there is a great deal more danger of the pipes clogging between the house and the tank than there is from the outlet of the tank. To save expense and subsequent difficulties, the distance from the wall of the house to the tank should be reduced to a minimum.

The top of the tank must be somewhat lower than the lowest point in the building from which liquids are to flow, but care must be taken not to get it so low that the effluent cannot flow away from the tank, or that water from the outlet can flow back into the tank at high-water periods. In some instances tanks have been placed very low in order to receive the liquids from the basement, and during rainy periods the water in the outlet ditch became so high that it forced water back through the tank and filled the basement. This is one of the most important factors to be looked after in the location of the tank. Tanks properly constructed, and with a good outlet, will very seldom need any attention or need to be opened.

Cleaning. It is possible that the tank will need an occasional cleaning out. This will depend considerably on the quantity of sand and sediment carried by the water used in the house. Practically all water carries some sediment, which will be deposited in the tank. In addition to this, more or less sand and soil find their way into the tank from washbowls and laundries, owing to the fact that persons working out of doors carry more or less dust in their clothing and on their persons. However, this does not fill up a tank very rapidly. It is exceptional when a tank requires cleaning more than once in five or six years, and many run much longer without any appreciable fill.

Construction. A septic tank can be constructed of any material that is reasonably water-tight. Where hard brick can be had at a reasonable cost, they can be laid in cement mortar, plastered on the inside, and thus make a very satisfactory tank. Where sand and gravel can be had at a small cost, the concrete tank is the most satisfactory.

A mixture of 1:2:4 should be used if it is select aggregate, or 1:4 if bank run. The concrete should be mixed fairly wet and tamped as it is put in place. The thickness of the walls shown in the figure is the minimum. If the location is in clay and a little care is exercised in the excavation, only an inside form is necessary. Where the soil is sandy and likely to cave or slip, it is essential that both an outside and an inside form be used. As the tank is out of sight, any rough lumber may be used for the form. The top can be made of 2-inch pine planks, laid across. Such a top will probably need to be replaced in seven years. The only advantages it has are the cheapness of first cost and the ease with which it is put in place. The best form of top is one made of reinforced concrete slabs, 4 inches thick, 18 inches wide, and with a length equal to the width of the tank plus the thickness of the two walls. These slabs should be reinforced with ¼-inch rods placed 4 inches apart and about one-fourth the depth from the bottom. Old horseshoes or bent iron rods may be placed in each of the slabs to serve as handles for lifting, and small pipe, old iron rods, or hayrake teeth may be used for reinforcement. These slabs can be molded at some convenient place, and when three weeks old placed on top of the tank. Their use makes it possible to do all the concrete work at one time and to remove the entire covering from the tank if desired. It avoids the need of placing forms inside the tank for overhead covering. For quantities of material, methods of mixing concrete, etc., see chapter on concrete.

A wide variation may be made in any of these tanks for the purpose of using materials that are already on hand, or to take the place of materials that cannot readily be purchased in the local market.

There is no great economy in constructing too small a tank. A tank 6 feet long, 3 feet wide, and 3 feet deep is as small as should be used for the smallest family; and the size should be increased whenever it is found too small to hold the quantity of liquid specified above. The size can be increased in any direction. Economical construction would require that a tank should be increased, ordinarily, in length after the inside dimensions are over 4 feet in width and 4 feet in depth. The deeper tank requires more expensive excavation, and a wider tank makes it more difficult to support the top.

SUMMARY

As soon as a tank is completed it should be used, and in a short time the bacteria will be working. In the course of a few weeks it will be giving efficient service. Acids of any kind should not be permitted to enter the tank, as they destroy the bacteria. Around creameries care should be taken not to pour liquid that contains acid into any of the drains that flow into the tank. Drains which carry acids should be connected with the outlet of the tank at a lower point. If these rules are complied with, the septic tank will be found satisfactory for the ordinary family. It is a much more sanitary method of disposing of the waste from the house than any other method that has yet been devised, and prevents much injurious matter from being carried into the streams or filtered downward into the soil, where it is likely to cause disease by polluting the water supply.

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CHAPTER XIX

HOUSE HEATING

HISTORICAL DEVELOPMENT

Progress. Years of progress have developed at least six styles of house-heating installation, aside from the old familiar first method, the fireplace, in which from 80 to 90 per cent of the heat generated went up the chimney. Real progress was made when the grate fire was moved to the center of the room and incased in thin cast iron or sheet iron, giving us the stove, and increasing the radiating surface 200 per cent. At the same time the size of the flue was reduced 75 per cent and the large loss of heat characteristic of the open grate fire was eliminated. Another step was made when the stove was moved to the cellar and a jacket placed around

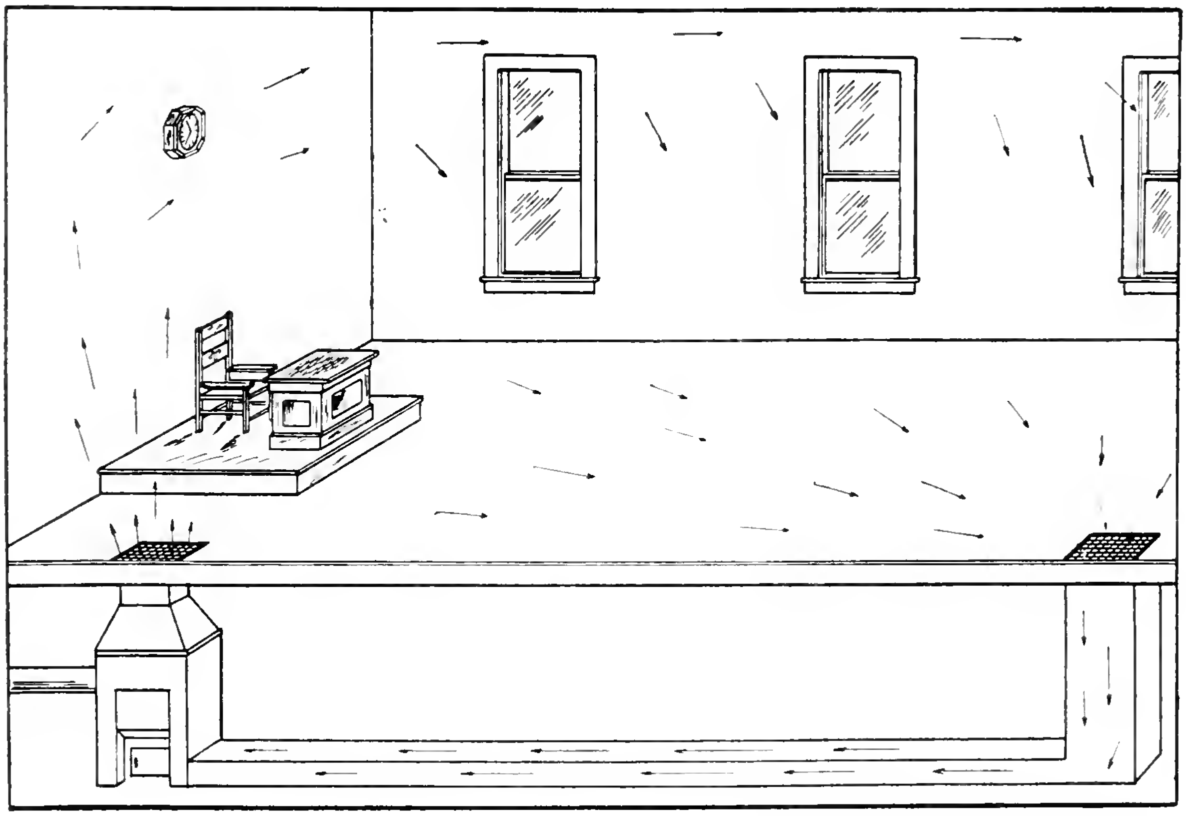

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FIG. 307. *Jacketed stove or hot-air furnace with air ducts*

it which opened through the floor to the room above (Fig. 307). With the neck of this jacket divided into two or more parts a hot-air furnace is produced which will heat two or more rooms, one for each pipe. Later developments gave us hot water and steam systems, and these now find some competition in the vapor system. There is also a combination system of hot air with hot water, steam, or vapor.

HEATING PRINCIPLES

Expansion. Before considering the effectiveness of these systems, it will be well to consider the fundamental principles upon which all of them operate. When a body is warmed, it expands and what was a pailful (of air or water) becomes more. In the case of water we can see some of it flow over the edge of the pail. The pail is still full, but the water does not weigh so much as it did. If this pail of water were placed in a tank of cold water, it would float — only for a time, however, because it would give up its heat to the colder water and both would become of the same temperature. The same is true of air. A heated body expands because of the vibration of the particles of which the substance is composed. The hotter the substance, the more vibration, and when each particle is using more room in order to vibrate, the whole mass of particles requires a larger space.

Mobility of air and water. Putty and clay are very soft and are called *plastic.* Air and water are called *mobile*, because they are more than plastic; the particles of which they are composed will easily slide over one another. An automobile or train displaces the air, and the inflow of air behind it causes what is known as *suction* and is visible because of the dust picked up by this current of air. Water does the same thing when a boat passes through it.

Convection. This mobility of air and water makes them ideal carriers of heat. It makes it possible to have a fire in the cellar or in an adjoining building and conduct the heat to any point desired, provided the heater is below the point to be heated. Heat is transmitted by conduction, radiation, and convection, but convection is the agent made use of in carrying the air or water from the source of heat to the region to be warmed. The outside of a stove becomes hot from the fire within, which heats the air in contact with it. This air in turn becomes lighter, rises, and is replaced by cold air from below and at the sides. This displacement of warm air by cold air continues and produces currents as indicated by the arrows in Figure 308.

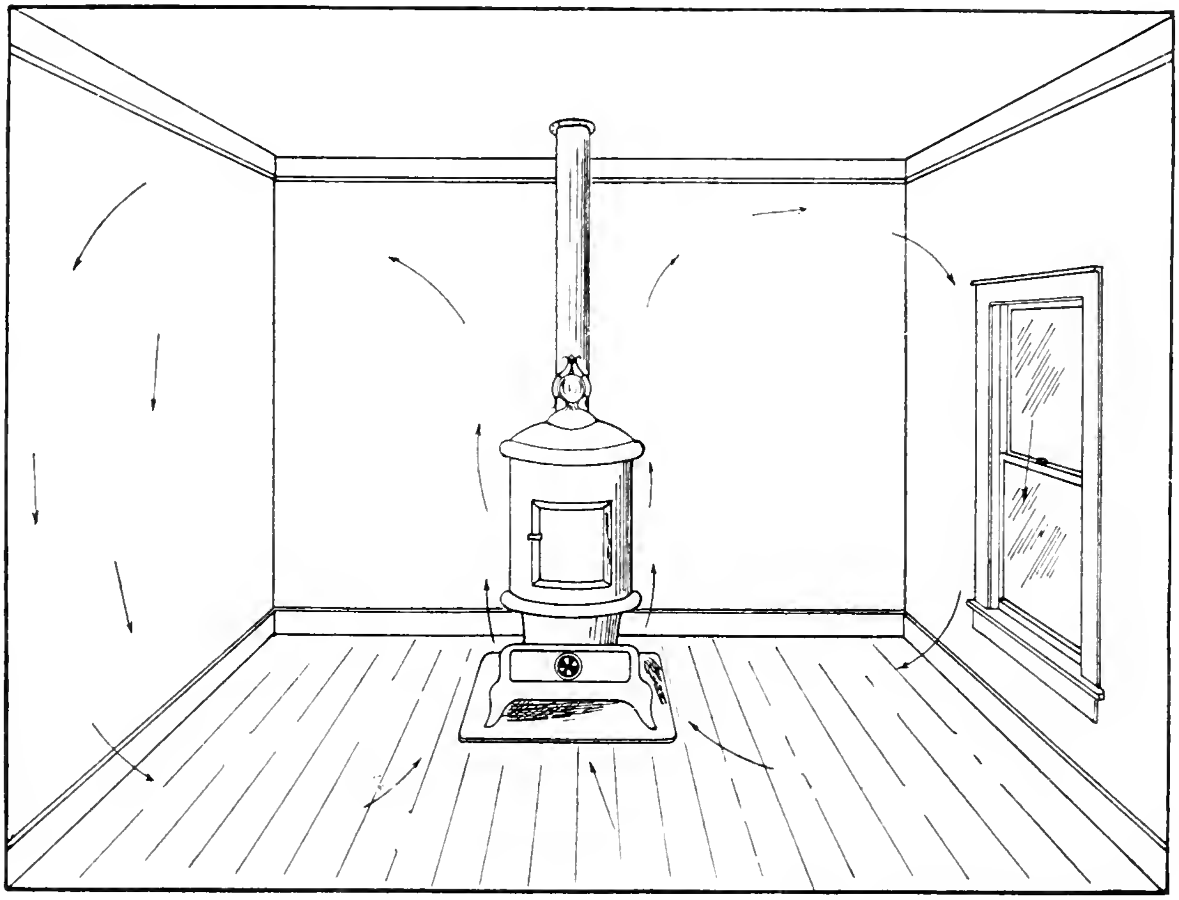

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FIG. 308. *Circulation of air produced by a stove. The arrows indicate the direction of the air currents.*

A clear idea of circulation or convection may be gathered from a study of Figure 309, page 404. An open tube of water is held so that the flame strikes it a short distance from the bottom. At this point the water will begin to heat and expand, will become lighter than the water above it, and so will rise from *M* to *N*, and the cold water at *N* will flow down as indicated by the arrows. A little very fine sawdust placed in the water will show the action and direction of the current, up on the upper side of the tube and down on the lower side. This will circuit *M* to *N* and will continue until the water boils. It cannot be made any hotter than this unless the top of the tube is closed.

One thing to be noted is that the water at the bottom of the tube has not become heated like that above the flame. It has gathered some heat by being in contact with the water above, but there was no circulation — the sawdust below the flame did not move. The tube may be held by this lower part all the time the upper part is boiling without burning the fingers. This shows that there is nothing gained by having a vessel extend below the source of heat. All water below this point is excessive and has no value in a heating plant, for it does not circulate. The proper arrangement of heat and water is shown in Figure 310. The water here is all above the flame. If a tube of this kind is extended through the floor from the cellar and a flame applied at the lower end, we have, in principle, the hot-water heating system. The hot water will rise from the base, give off its heat to the air surrounding the tube in the upper room, and fall again to the flame to be reheated. The same tube might be extended to the second floor and heat that also. If less heat is required, the tube may be reduced in size and the water will not

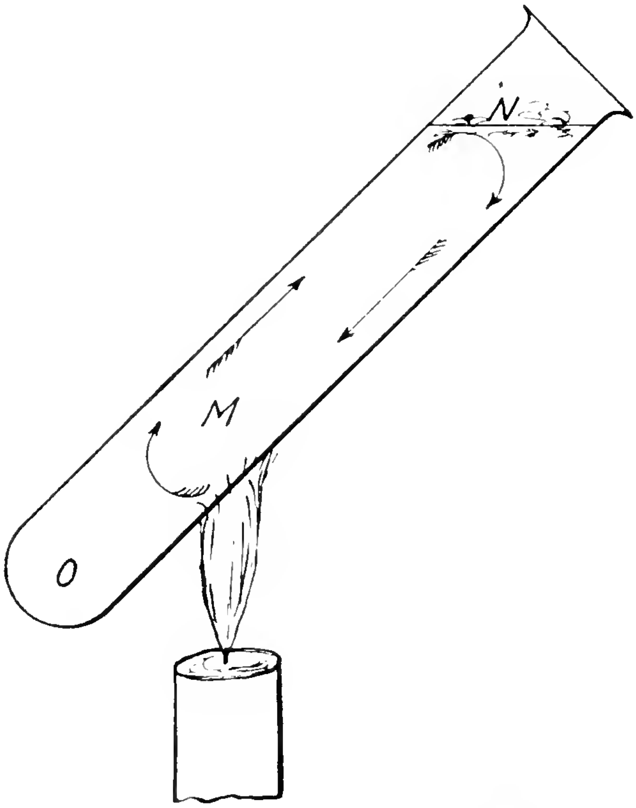

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FIG. 309. *Circulation of water produced by the application of heat*

circulate in such large quantity. There is naturally some friction between, and mixing of, the currents rising and falling in the same tube. This can be eliminated by the use of two tubes connected top and bottom as in Figure 311. Heat may be applied just a little off the center and the circulation will be up one side and down the other. With this the circulation is more rapid and the tube may be smaller and yet the heat transmission the same.

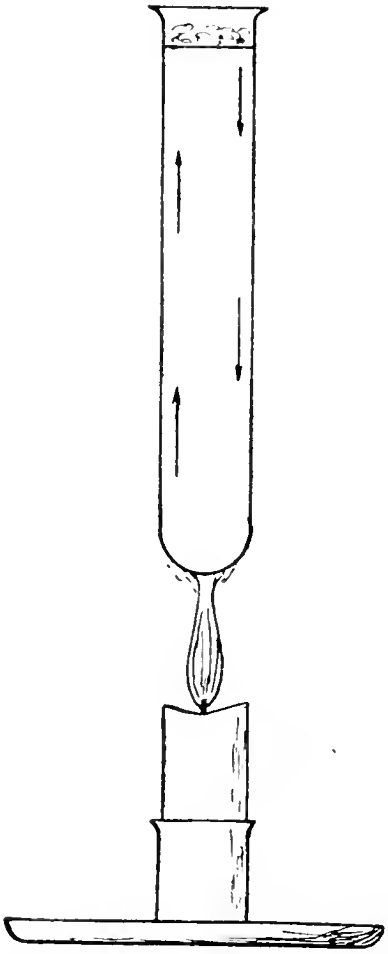

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FIG. 310. *Proper arrangement for heating water*

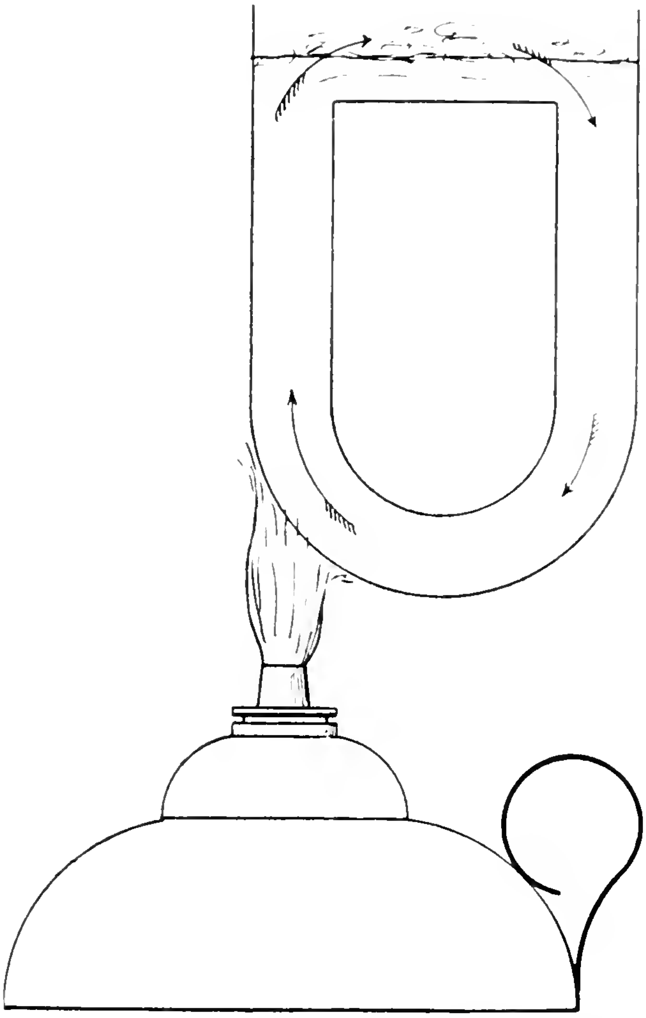

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FIG. 311. *Use of two tubes causes the water to flow more rapidly.*

Air circulates in the same manner as water, but not quite so positively. Air will not circulate through a single pipe, because the difference between the weight of hot and cold air is too slight. It must have two pipes, a riser and a return pipe.

TYPES OF HEATING APPARATUS

Fireplace. Where the climate is very mild, a fireplace may afford all the heat necessary. In a section of the country where wood is plentiful the comfort and satisfaction of an open fire should not be overlooked. In early spring and late fall a few sticks of wood on a grate fire will afford more cheer than double the quantity in a heater. The flue should be large — one 8×8 inches is usually too small. A fireplace should be at least 36 inches wide, 28 inches high, and 16 inches deep, or as near these dimensions as the commercial facing and lining materials will make. Colored brick with a rough face makes a most satisfactory facing and may be placed at the time the chimney is built. The lining should be of fire brick. A hearth is easily built of a smooth, hard brick or tile. Figure 312 shows a section of a fireplace showing facing, lining, damper, ash trap, throat, and smoke box. The essentials of a satisfactory fireplace are: (1) a large flue, (2) a smooth throat set well to the front, (3) a thin lip. A smoking fireplace can usually be remedied by the addition of a thin lip member.

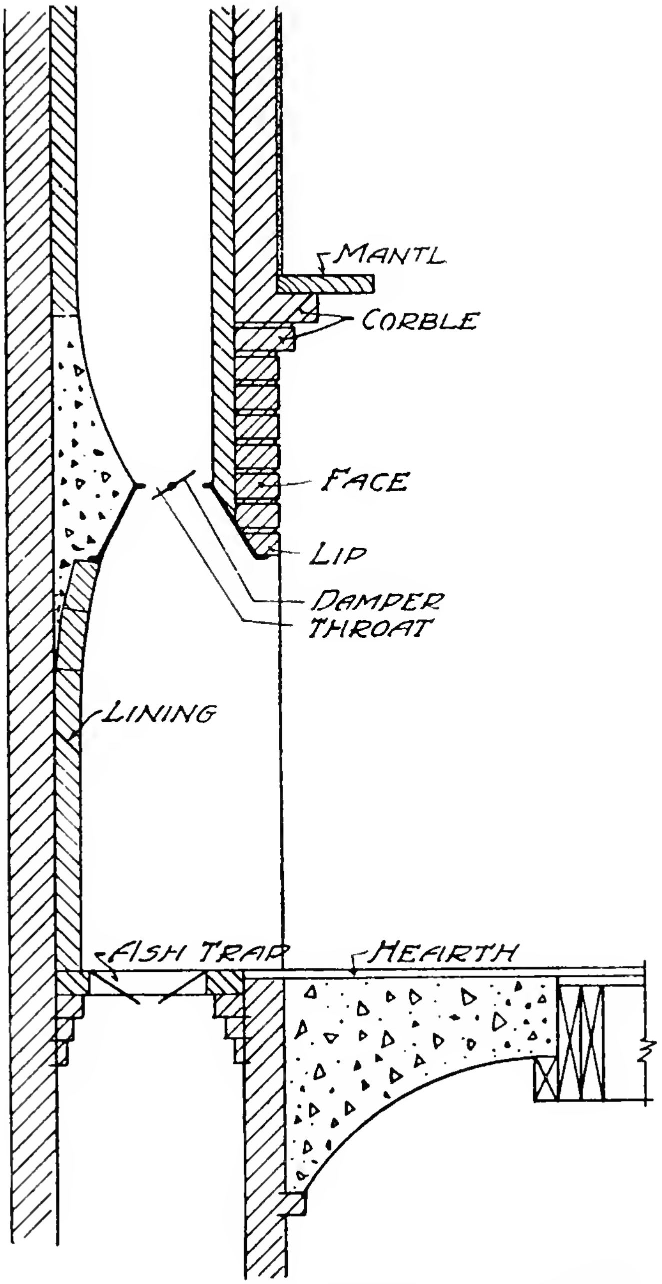

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FIG. 312. *The essentials of a fireplace*

Stoves. A room of ordinary size can be made comfortable with a stove when it is not too cold outside. If it is very cold outside, say 10° below zero, the current of air will become so cold while passing down the cold walls that the stove cannot heat the room comfortably. A sheet-iron jacket, with neither top nor bottom, set up from the floor as

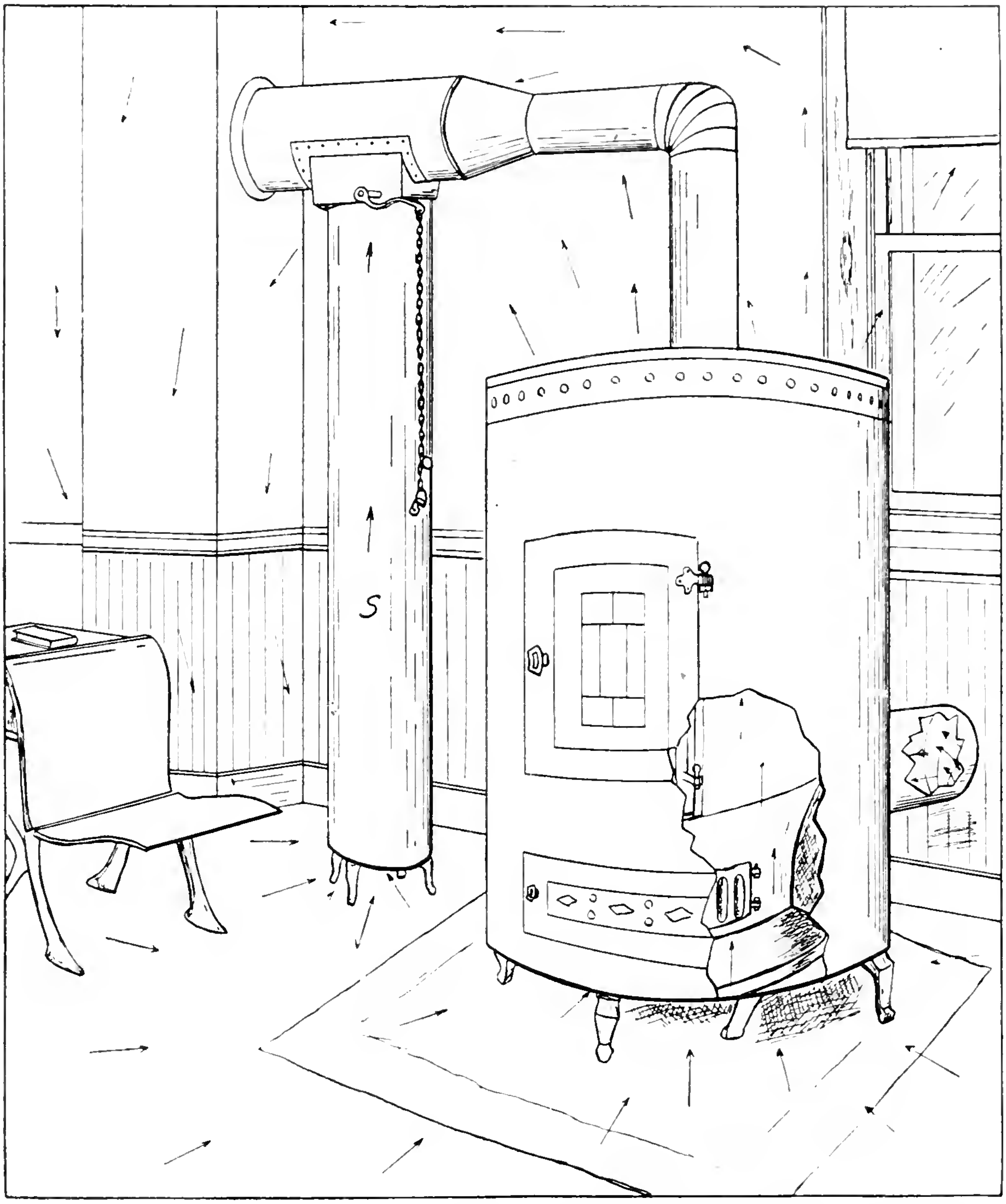

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FIG. 313. *Stove with sheet-iron shell. This stove has also a sheet-iron jacket to quicken the circulation of the air.*

in Figure 313, will increase the rapidity of air circulation, since only the air within the jacket is heated. This air becomes hotter and rises faster, thus making a more rapid circulation and a more efficient heating system. The objections to this sheet-iron jacket are that the stove proper gets so hot that the air is burned (dried to excess) in passing up through, and the cleaning and firing are difficult owing to the distance through to the fire box. Another device is a drum or radiator attached to the smoke pipe just over the stove or in an upstairs room (Fig. 314). It is a simple device for increasing the size of the pipe for a short distance, thus allowing more heat to leave the smoke and remain in the room.

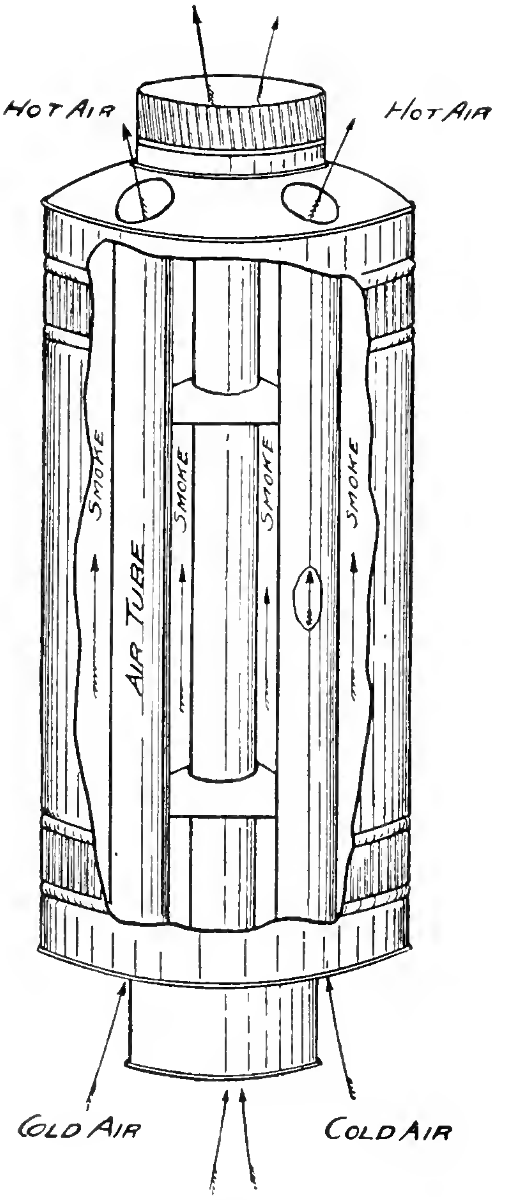

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FIG. 314. *Drum for extracting heat from smoke. The drum is placed above the stove or on the second floor before the pipe enters the chimney.*

Hot-air furnace. A stove with a jacket, placed in the cellar, becomes a furnace. A brick wall may be substituted for the steel jacket. A return flue through the floor some distance from the furnace makes the system complete. Such a scheme is used for many churches and assembly rooms where the basement can be used as a furnace room. This method is now known as the pipeless furnace.

When this furnace is set a little lower in the ground and the neck is divided into several small pipes, it may be used, as shown in Figure 315, to heat several rooms. Heat is conducted to the second-floor rooms by rectangular pipes

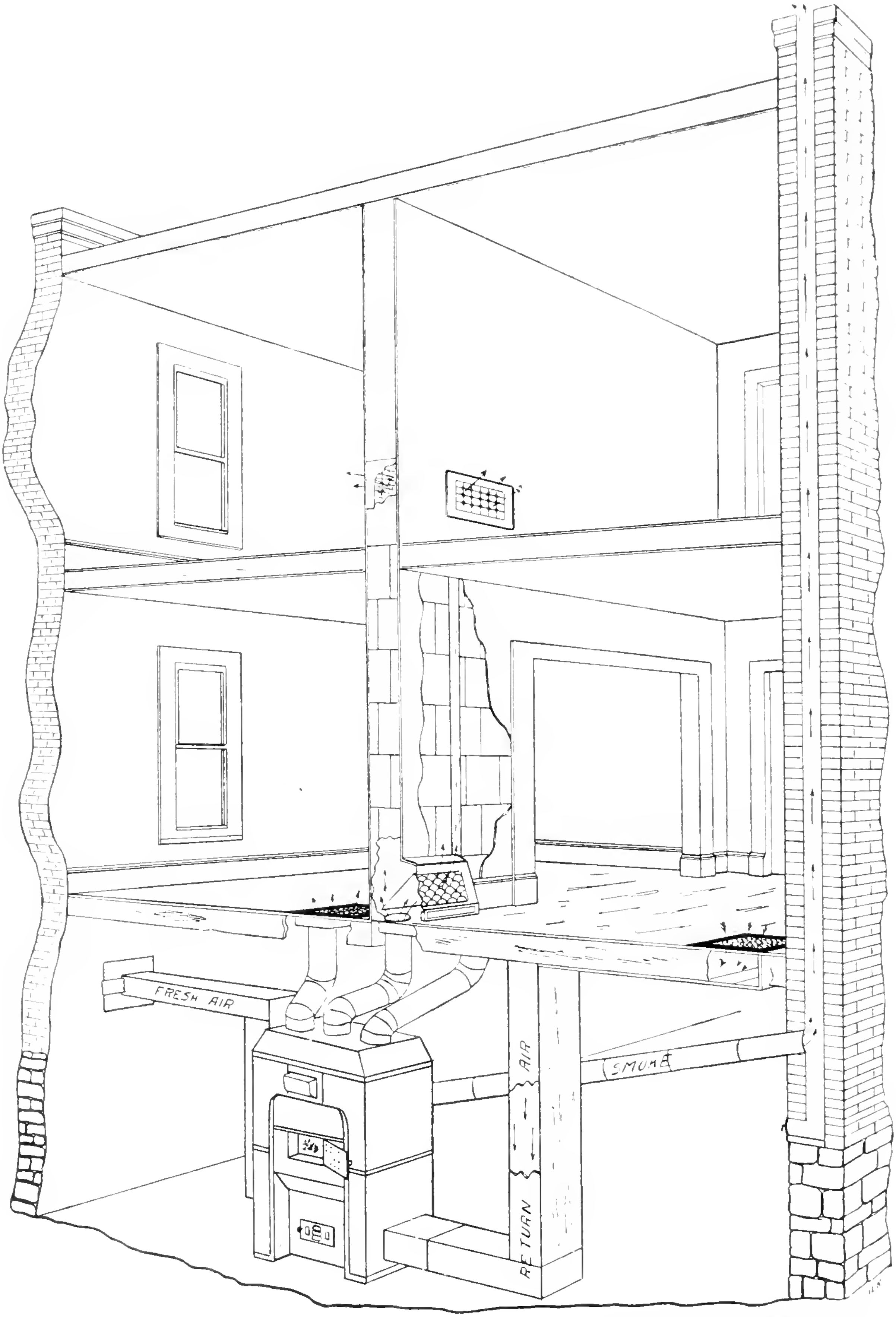

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FIG. 315. *Hot-air furnace. Pipes to different rooms, registers, fresh-air duct, and return duct are shown.*

set in the walls between the studs. Over each opening in the floor or walls is a register of perforated cast iron, as shown in Figure 315.

In each pipe leading from a furnace is a damper so that any pipe may be closed at will. There is a return air duct, to be used when the weather is too cold to allow the heated and used air to pass out of the house. The rooms are full of air at all times, and more air cannot be forced into them by the small pressure exerted by the warm air in the pipes below. In order to get this warm air into the rooms, a way must be provided for the cold air to escape. This is done by means of a return air duct, which may open into a chimney and allow the air to pass out, or under the furnace and permit the air to be reheated and returned to the room. When this is done, the fresh-air duct may be closed or partly closed.

First-floor pipes should not be less than 12 to 16 inches in diameter. Second-floor rooms must be reached through rectangular ducts, about 4 × 14 inches in size between studding. Unless special construction allows a large pipe to the second floor, it will be found difficult to heat upper rooms, especially to windward. All pipes in cellar and in walls should be covered with asbestos paper to protect the pipes and to save heat. This covering should be water-proofed to prevent absorption of dampness during summer months. The dampness hastens the rusting of the sheet-metal pipes. A damper in every pipe and also in the smoke flue will aid materially in controlling and distributing heat.

Hot-water system. A hot-water system is only a slight elaboration of the principle illustrated in Figure 311. Enlarge the base to inclose the fire and reduce the size of the tube or pipe between the fire and the rooms to be heated, make that part of the circuit in the room large, to give enough radiating surface, and the result is the system shown in Figure 316. The main body, *A*, cast in sections for convenience in handling, is often made quite irregular in order to expose more surface to the fire. Water is conducted through a large pipe, *B*, from which smaller pipes connect with one end of the radiator in each room. The other end of the radiator is connected to a large return

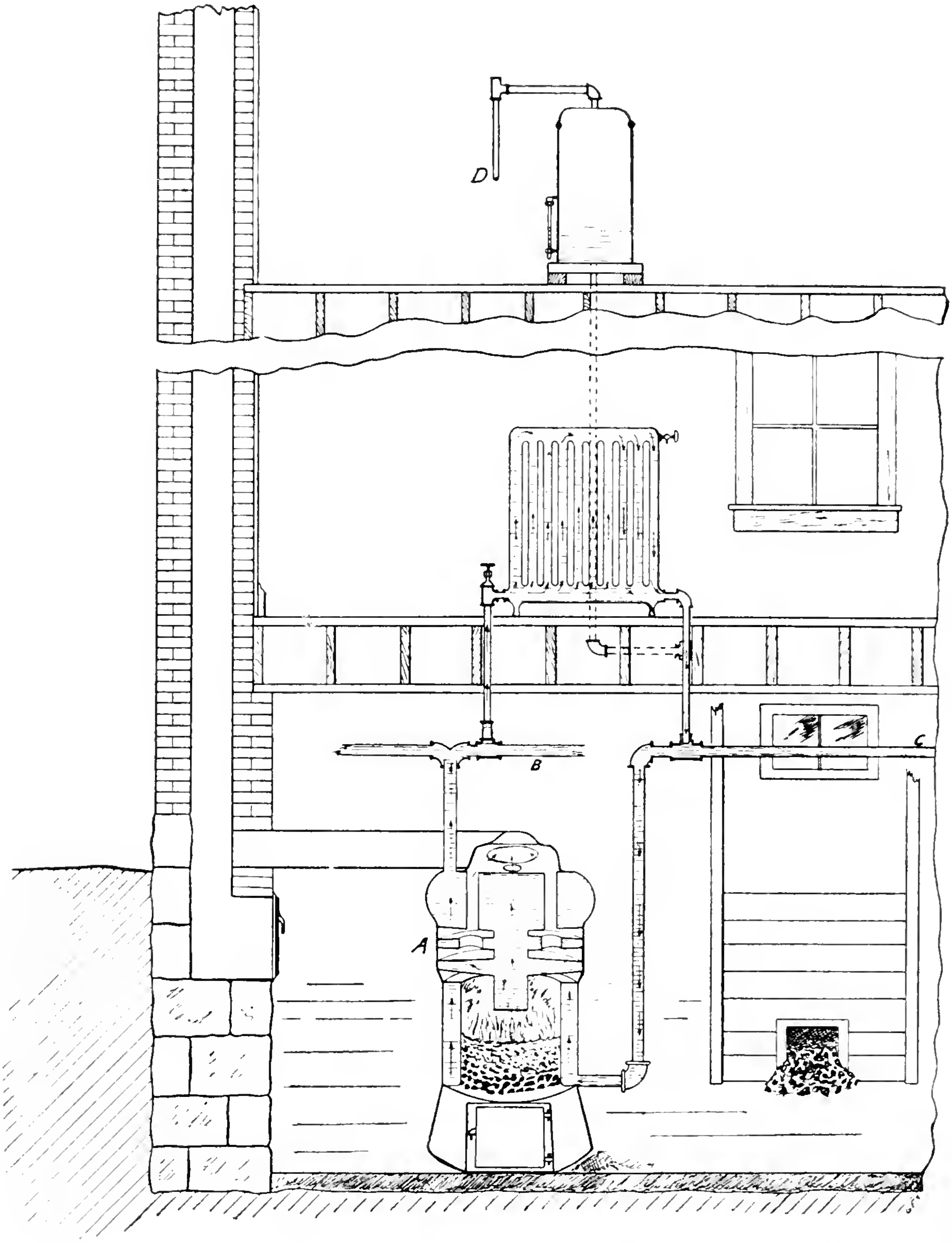

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FIG. 316. *Hot-water system*

pipe, *C*, which enters the heater at the grate level. This allows for a more rapid circulation than if a single pipe were used for each radiator.

Allowance must be made for the expansion of the water. This is done by means of an open tank placed in the attic, or in a second-floor room above the top of the highest radiator and connecting with the system at some convenient point, as shown in Figure 316. The system may be filled through this tank if there is no pressure system at hand. This is called the open-tank hot-water system. If the tank *D*, in Figure 316, were capped tight, and little or no water reached the tank, there would be a quantity of air confined which would be compressed, because the water in the heater, pipes, and radiators expands when heated. This is the closed-tank or semi-steam system. The advantage is a higher temperature of the water before the boiling point is reached. The higher temperature will allow smaller pipes and smaller radiators, and the practice is to install a smaller heater also. The cost of installation will be less in consequence. The objection to this semi-steam system is the need of safety devices, which may fail, and harder firing, which requires more fuel.

Hot-water pipes. A hot-water system may be installed with the most economical results after the house is built, for then the pipes are all exposed and add to the heating surface in the room. It may be put in when the building is being erected, as shown in Figure 317, where all pipes are concealed in the partitions. Never conceal a pipe in an outside wall; too much heat is lost. All pipes should be so placed that there are no pockets or traps in them, and the return pipes should lie just a little below the corresponding feed pipe. This system will work without this precaution, but will work better if it is observed. A radiator with less than 40 square feet of surface should have a 1-inch pipe; one with from 40 to 80 square feet, a 1¼-inch pipe; and one with from 80 to 125 square feet, a 1½-inch

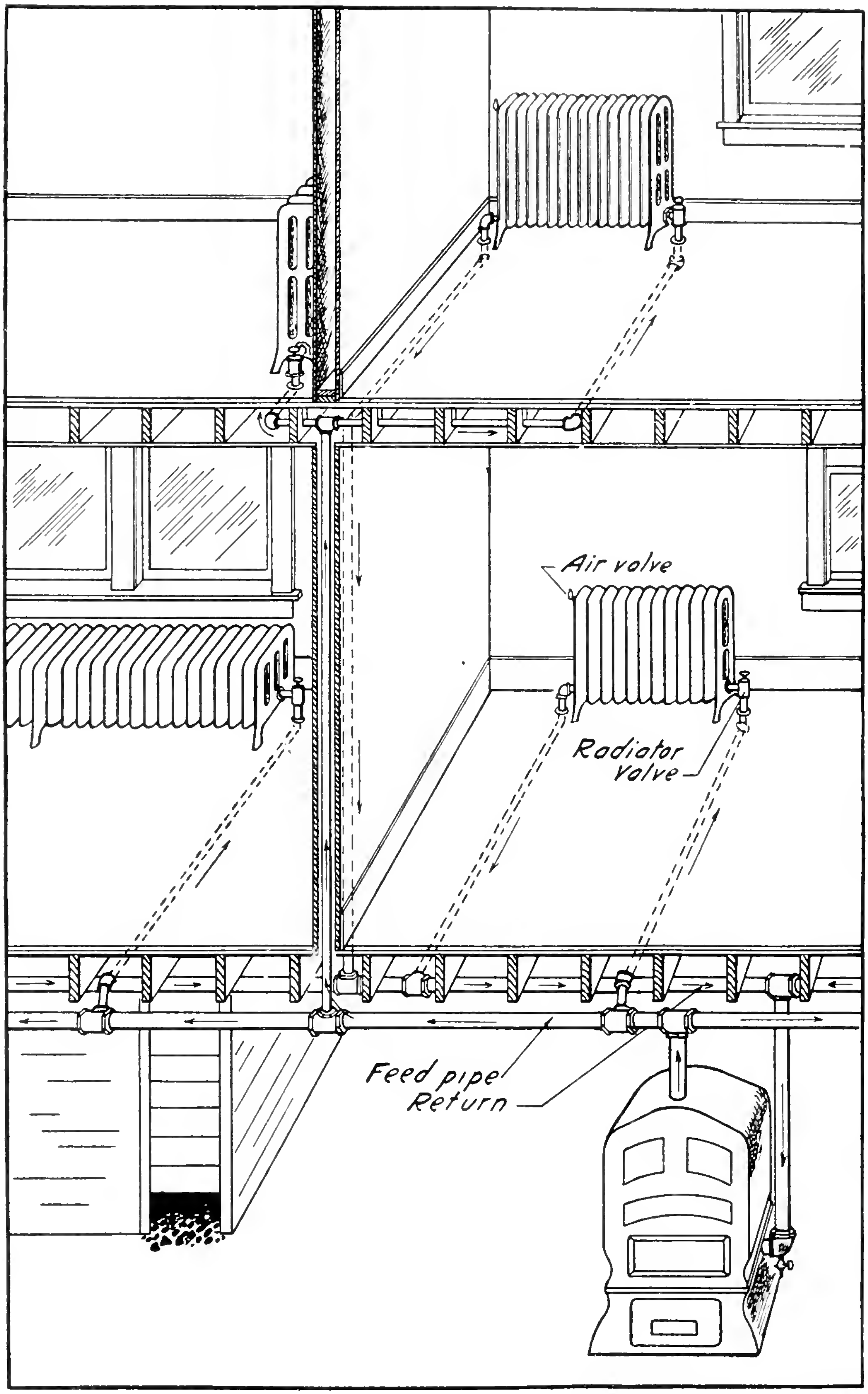

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FIG. 317. *Connections of a hot-water furnace with pipes and radiators*

pipe. All pipes should be reamed out, as the diameter is materially reduced when the pipe is cut with a wheel cutter (Fig. 318). This reduction is sometimes as much as 18 per cent and will naturally affect the flow of water.

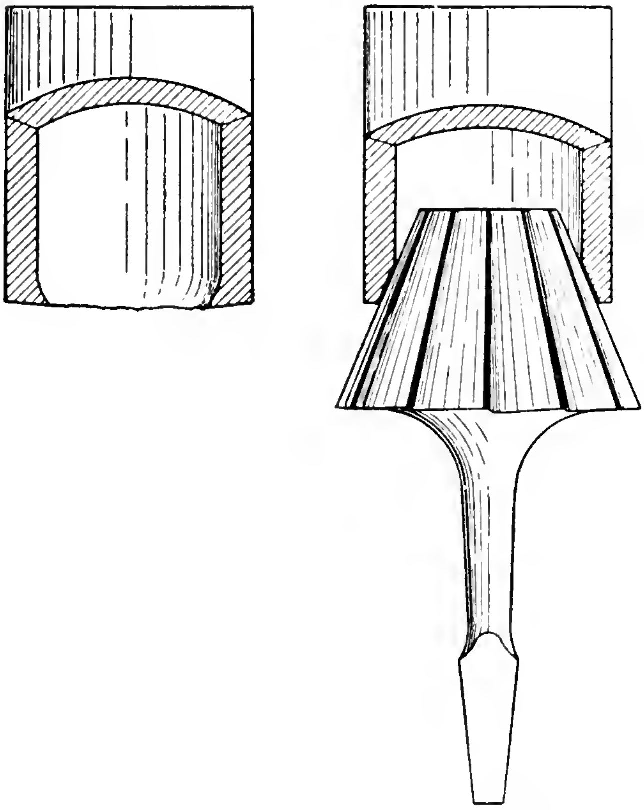

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FIG. 318. *A reaming tool*

Radiators. The size of radiators, their location, and their covering are all important. If possible radiators should be set against an outside wall; i. e., on the coldest side of the room.

All coverings check radiation, but paint checks it far less than aluminum bronze.

To determine the number of square feet of radiation for each room, there are several formulas, only one of which gives results large enough to cope with winters in the latitude of Minnesota, where a temperature of 15° below zero is frequent and one of 25° below not uncommon. The size of the room, window surface, and outside wall enter into the problem.

The following formula will give the radiation for a given room:

Find the cubic contents, in feet, of the room, and divide the number by 200. Find the number of square feet of glass in the windows and divide it by 2. Add to the quotients thus obtained the number of lineal feet of exposed wall and multiply by 2. The product will be the amount of radiating surface required for the room.

Suppose the room is 12×16 feet, with 8-foot ceiling, three windows 24×60 inches, and two sides of the room exposed.

$$\frac{\text{Cubical contents}}{200}+\frac{\text{Sq. ft. glass}}{2}+\text{Lineal ft. exposed wall}\times 2$$

or

$$\frac{1536}{200}+\frac{30}{2}+28\times 2=101.36 \text{ sq. ft. radiation}$$

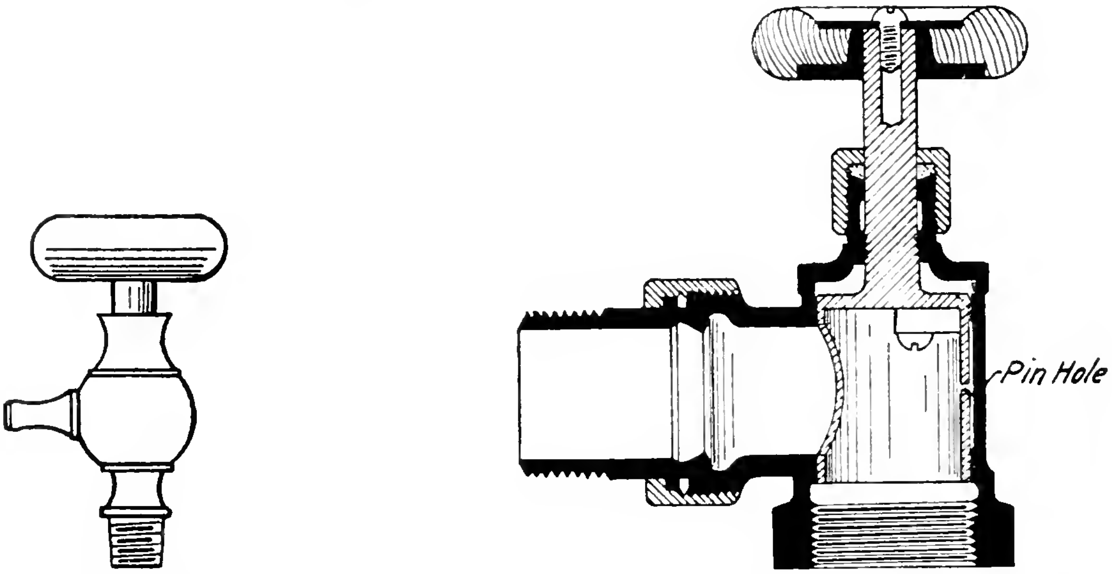
The number of sections giving nearest to 100 square feet should be used. For a second-floor room this can be reduced by one-seventh, or to 85 square feet. This radiation is ample for the coldest weather. If one is willing to shiver a little on cold days, the 100 feet may be reduced to 85 and the 85 to 62.

Another formula which gives sufficient radiating surface for latitudes such as southern Iowa and Illinois is as follows:

$$\frac{\text{Cubical contents}}{60}+\frac{\text{Sq. ft. exposed wall}}{10}+\frac{\text{Sq. ft. glass surface}}{2}$$

To the result obtained by the above formula add 10 per cent for a room with north exposure and 15 per cent for one with north and west exposure.

Size of heater. Add 75 per cent to the total number of square feet of radiation required for the house and buy the heater carrying the rating nearest to this quantity. Boilers are rated for zero weather, the very best fuel being used, and every foot of pipe and boiler being counted as radiating



Air valve (radiator)

Cross section of hot-water radiator valve

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FIG. 319. *Radiator valves*

surface. If installed on catalogue rating, they will prove inadequate when the thermometer stands at 20° or 30° below zero.

Steam. Little need be said about steam systems. They are like water systems in make-up, except that the expansion tank is closed or omitted. All water is in the heater and none in the radiators. There is no circulation until the water in the boiler is boiling and there is pressure in the pipes and radiators. This pressure, while not intended to be heavy, may become so if not watched carefully. Constant supervision is impossible in the average home. In the mill, factory, or large flat building there is reason for keeping a man on duty constantly, but not in the home.

Vapor or vacuum system. The vapor or vacuum system is a comparatively recent development. It is the opposite in principle to the closed-tank hot-water system, as the air is exhausted from the pipes and radiators and water stands in the heater only, as in a steam system. The exhaustion of the air makes it possible to produce steam at a temperature somewhat lower than 212°, which means that a small fire will produce results in a few minutes, because there are only a few gallons of water in the heater. It is virtually a steam system and requires protective devices as carefully adjusted and attended as a steam system. Furthermore, leaks in the system will destroy the vacuum and it will become a steam system pure and simple.

Ventilation. It is asserted, and with reason, that special ventilation devices are not necessary in the average house. There is a larger air movement through walls, around windows and doors, and up stairways than is generally realized. Observations would indicate that there are from one and one-half to two changes of air per hour. From this it may be concluded that the only ventilating provision necessary in a residence is a fireplace flue, with a damper which may be closed except when the house is occupied by a large number of people.

Power ventilation systems are used in large public buildings, but they cannot be economically installed or operated in the residence, small school, or public meeting place. There are many simple methods of securing an influx of fresh air and at the same time preventing draughts and zones which are distinctly lower in temperature than the air in other parts of the room. Among these may be mentioned a deflection board or baffle set in front of a slightly raised window, a muslin-covered frame inserted instead of or in conjunction with the baffle, a hinged pane of glass where the windows are made up of a number of small lights, and where double windows are used the outer hung to open at the bottom and the inner to open at the top. Transoms over doors leading to the halls aid materially in the movement of air, especially in a building of more than one story. An open stairway acts as a flue, and the movement of air is distinctly upward through it.

Automatic controls. To obviate the necessity for watching the temperature of the house, simple devices, known as *thermostats*, have been invented which will open or close dampers and drafts with changes in temperature. These devices involve the old principle of expansion and contraction of metals and liquids with changes of temperature. They are simple and require little adjustment or attention. With the most common type two or three dry cells once a year are needed.

FUELS

Coal. Fuels vary in actual value as much as wheat, potatoes, butter, or any other article of commerce. Coal is graded and priced, however, according to size instead of quality. The finer the coal, the larger the percentage of dirt, rock, and slate. Coal measuring from 3/16 of an inch in diameter to 9/16 is called buckwheat; that from 9/16 to 7/8 of an inch, pea; that from 7/8 of an inch to 1½ inches, nut; that from 1½ to 1¾ inches, stove; and that from 1¾ to 3 inches, egg. Buckwheat is the cheapest grade and nut the highest priced. Hard coal gives off but little more heat than good soft coal, and about one-quarter more than the ordinary soft coal. More heat is obtained from hard coal because there is very little soot. When soot collects on the heating surfaces, it prevents the passage of heat to the water or air of the system. For hard coal a deep fire box gives best results. Hard coal burns slowly and requires less air than soft coal or wood, and the deep fire serves as a check on the air. Soft coal and wood burn best in a thin layer over a larger surface and require more frequent firing.

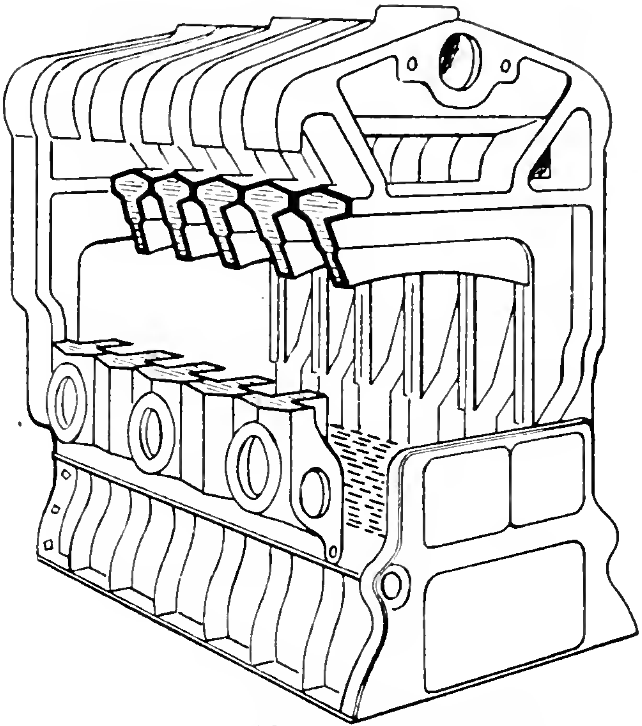
Firing. Economical stoking is an art. Hard coal is popular because the average person does not care to fire every half-hour. However, a little admixture of brains with the coal will pay, even with hard coal. In general, add as small a quantity of coal as possible at each firing, and fire often. Do not entirely cover the bed of live coals, but leave a small hole, where sufficient heat can get through to fire the gases as they distill off from the coal; otherwise they are lost up the chimney. These gases burn clear and hot and form a large part of the coal. Keep the grates clean and clear of clinkers. Use a slice-bar, and prevent a tendency to cake at the bottom of the fire.

Coke. Coke is formed from a soft coal partly burned without sufficient air for complete combustion. After the smoke and soot have been driven off, the fire is quenched with water. What is left is light and porous and burns well. Coke may be made of lignite or peat. The market offers a petroleum coke, which is not coke at all, but a residue from oil-refining retorts.

Wood. Wood may be used in sections where it is plentiful and can be had without a long freight haul. Two cords of wood equal in heat units, approximately, a ton of good coal. A cord of wood is 8 feet long, 4 feet wide, and 4 feet high.

Briquets. Briquets are now offered for sale at about the price of coal. They are made of coal screenings with a little oil or asphalt for a binder. They make a good fireplace fuel.

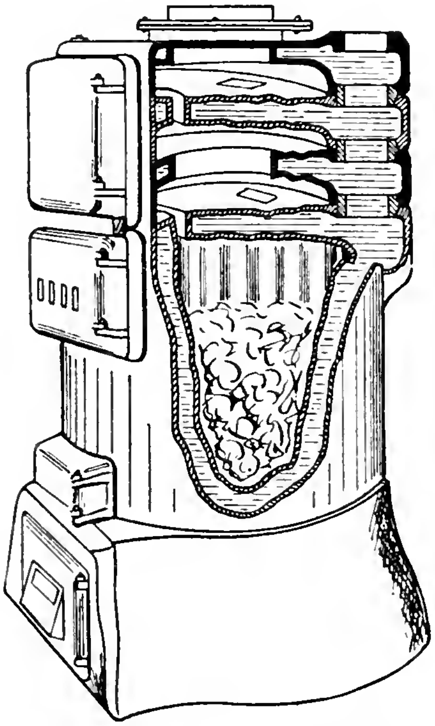
Oils. Low-grade oils for heating are not popular at a distance from oil wells because of the freight charges. Where oil is plentiful, the railroads use it exclusively. It is burned most successfully where pressure is convenient to spray oil into the fire box.



After University of Minnesota

FIG. 320. *Sectional boiler, showing water columns and passages*

Gas. Gas, like coke, is excellent for a high local heat. Complete combustion takes place within a small zone. For this reason these fuels are not popular in ordinary heaters where a large combustion space is provided.



After University of Minnesota

FIG. 321. *Round, back-connected hot-water boiler. This style of heater has a deep fire box and no water arms.*

Electricity. Electricity is expensive for heating and cooking purposes. An electric iron is the only appliance which is economical as compared to the old way. For general purposes, electricity would have to sell for 2½ cents per kilowatt hour to compete with coal for heating and with gas and wood for cooking. Prices now range from 10 to 15 cents per kilowatt hour.

Considerations and precautions. All-round steam and hot-water boilers are made for hard coal. A

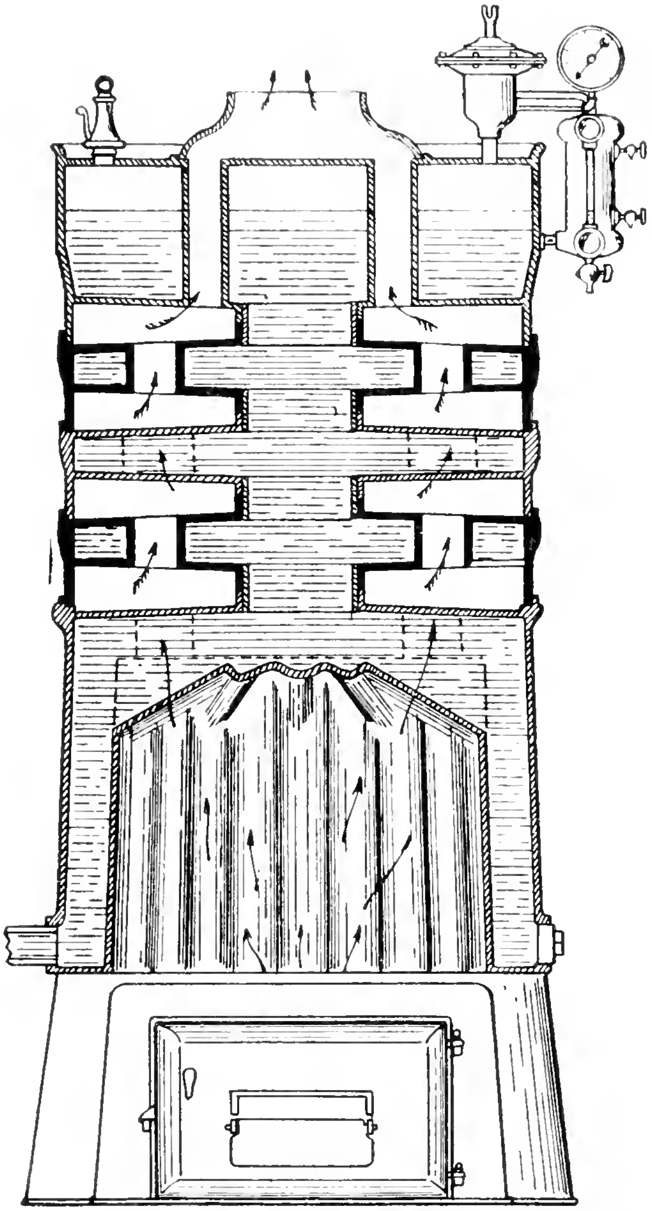


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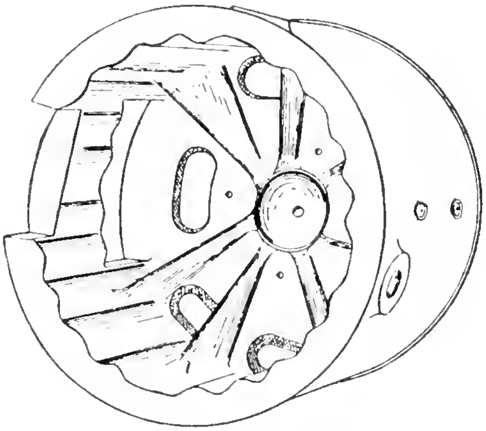
FIG. 322. *Round, center-connected boiler with water arms*

sectional boiler may be lengthened by the addition of sections and the size of the fire box be thereby increased (Fig. 320). In round hot-water boilers two styles are offered, one with a flat-top fire box (Fig. 321), and one with water arms, as shown in Figures 322 and 323. The one with the flat top is much more easily cleaned than the one having water arms, and the heating coil is more easily installed. The latter style is intended to give more heating surface in the fire box.

Figures 321 and 322 show two methods of connecting the water plates or sections. Figure 321 has a single opening between sections at the back. Some have smaller openings on each side. Figure 322 shows a center-connected heater. Figure 325 shows a good type of hot-air fire box. It is made of boiler iron and is riveted tight. This fire chamber will last as long as the rest of the furnace, but not so long as the cast-iron sections.



After University of Minnesota

FIG. 323. *Fire-box section of hot-water or steam boiler with water arms*

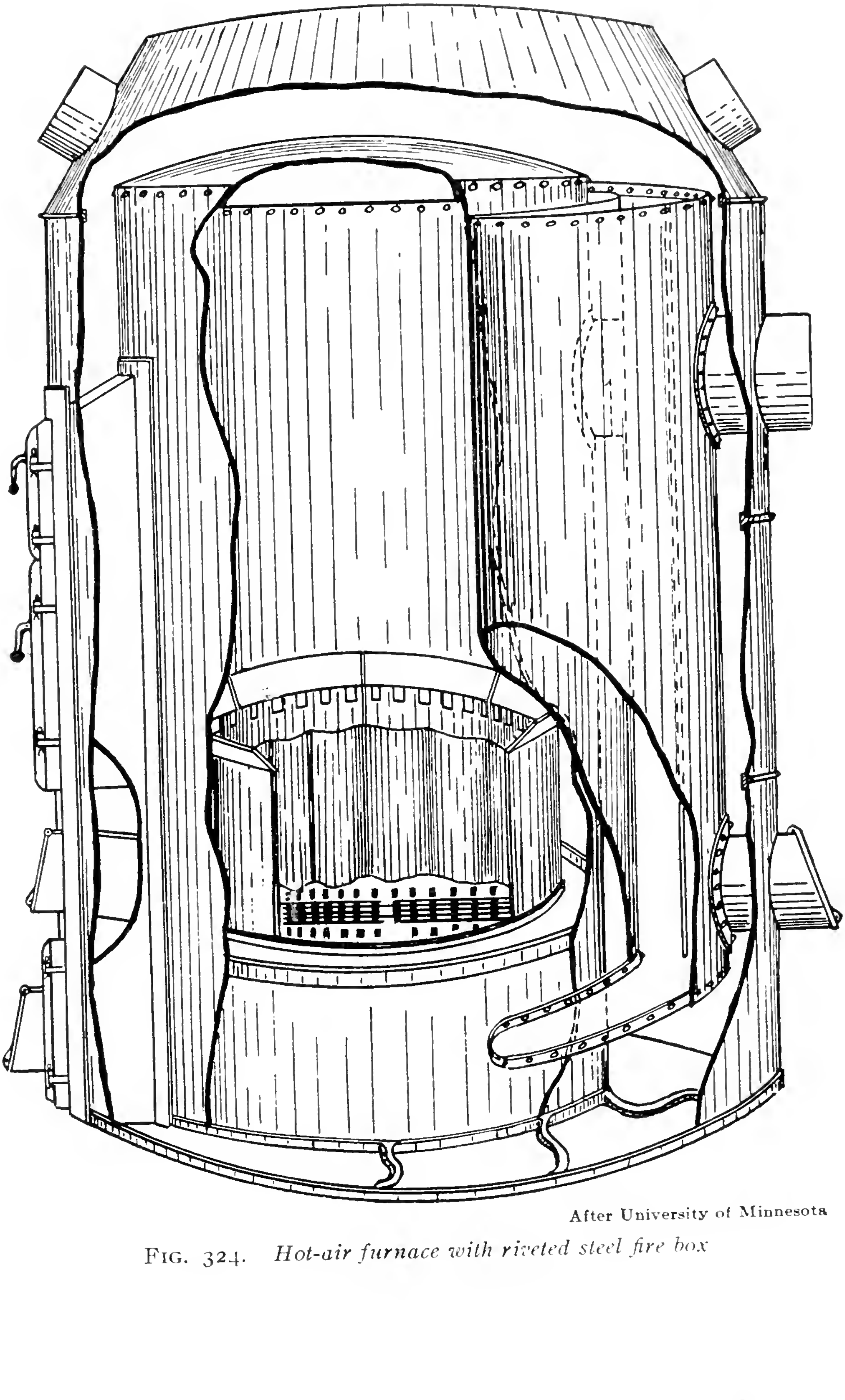


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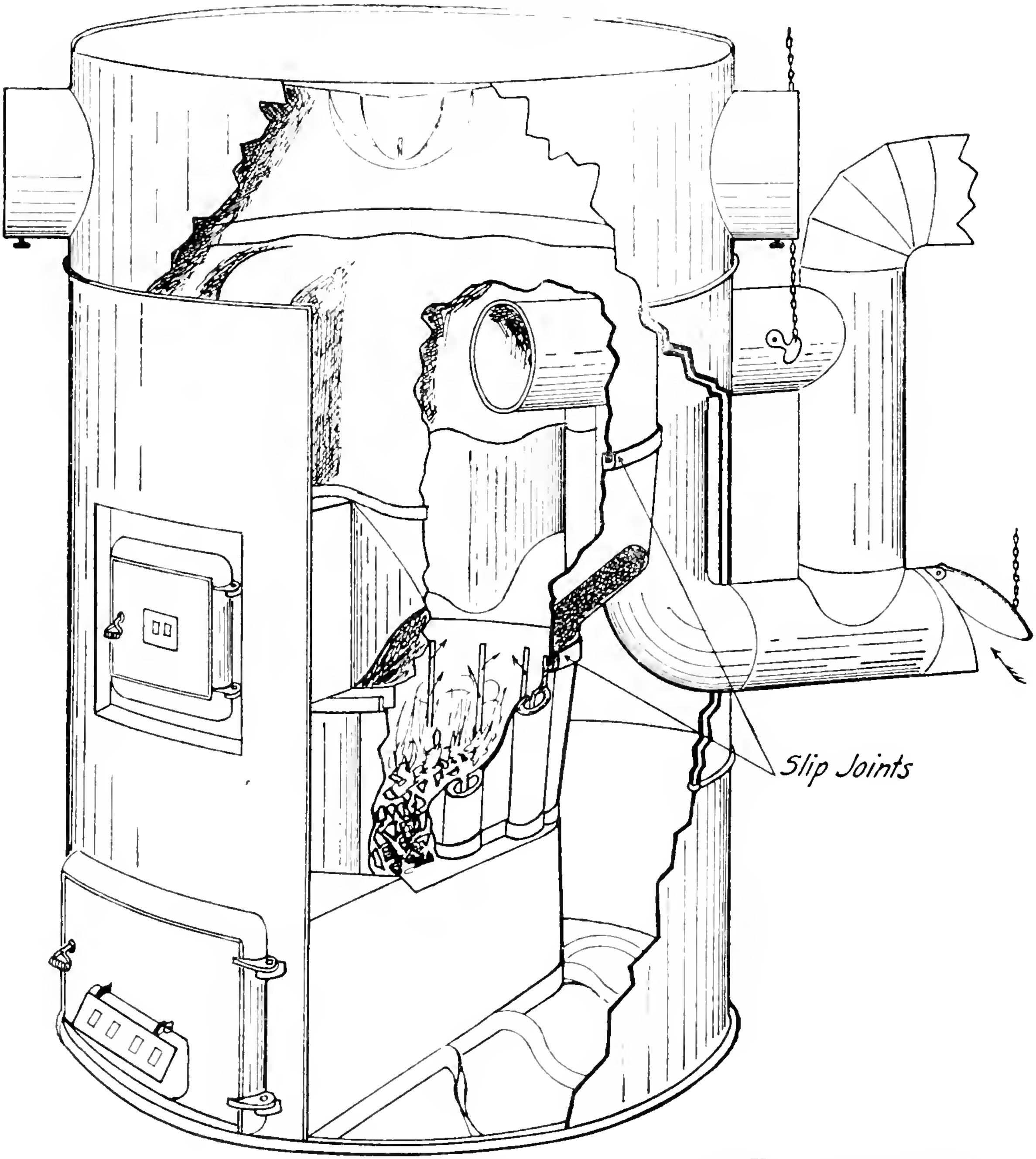
FIG. 324. *Hot-air furnace with riveted steel fire box*

When any heater is put in place the clean-out doors should not be backed up against a chimney or partition.



After University of Minnesota

FIG. 325. *Hot-air furnace with slip joint, cast-iron type of fire box*

SUMMARY

In the choice of a system for heating a farm home the decision is generally between a hot-air furnace and hot water. Both systems present certain advantages and disadvantages. With the hot-air furnace heat can be quickly raised in a cold house and the air kept moist by a water pan in the furnace. When properly installed with outside air ducts, it is an aid to ventilation. Much of the criticism of this system is due to the fact that it has been used to replace the stove in old houses, where there was not enough room in the basement or sufficient space in the partitions to allow a proper location of the furnace with pipes of an adequate inclination and size. The desire for economy often leads to faulty installations and improper provisions for the return of the cold air. When of sufficient capacity for the average-sized house, the fire box is made in sections which, when not properly fitted together, result in smoke and gas in the rooms. Difficulty is sometimes had in carrying heat to rooms to the windward of the furnace. To be successful in cold climates, the furnace must be large and the pipes from 50 to 100 per cent larger than are ordinarily used in moderate climates.

With the hot-water system considerable time is required to raise the temperature of a cold house, owing to the volume of water to be heated. Neglect of preventive measures may lead to flooding from leaky joints or from frozen pipes when circulation is not kept up, the settling of dirt upon the walls above the radiators, and difficulties in regulating temperature in mild weather. These disadvantages are balanced by the complete control of the circulation of the heat, the small space required in the basement for the furnace and piping, and the fact that upstairs rooms can be heated as readily as the ones in the lower part of the house.

The cost of a hot-water system is considerably more than hot air, on account of the more expensive piping used in the distribution of the heat, but the life is proportionately longer.

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CHAPTER XX

LIGHTING

Candle power. The candle is the unit by which light is measured. A standard candle is one that burns a fixed quantity of a specific quality of sperm oil in an hour. An ordinary candle is a little stronger than a standard candle. A 16-candle-power light will give illumination equal to sixteen standard candles, or about fifteen ordinary tallow candles. It does not follow that the 16-candle-power lamp will produce a better light in a room than the fifteen or sixteen candles if the latter are properly distributed. To illuminate a room satisfactorily by candles is considered too expensive. The secret of the economy is that the large unit is in all cases more economical than the small, though the distribution may not be as satisfactory.

Kerosene lamps. Kerosene lamps have been equipped with mantles producing a good light, and at a price which would keep all others out of the field. The mantle is frail, however, and a portable lamp using a mantle of the soft-fabric construction is not satisfactory.

GAS

Oil gas. Gas for lighting purposes has been known for many years. The common name applicable to all gases so used is *air gas*. This implies a mixing of air with a small quantity of vapor from a volatile oil — in short, a carbureting of the air. This gas is not satisfactory when burned in a flat frame or open burner. It requires a mantle in order that reasonably constant results may be obtained with the varying quality of the gas. The most common of air-gas plants is the one that uses gasoline. This system has fallen into disfavor because of the gradual lowering of the grade of gasoline commonly found on the market. Some systems have attempted to use kerosene, and have failed, as have the gasoline plants, because of the poor quality of oil used.

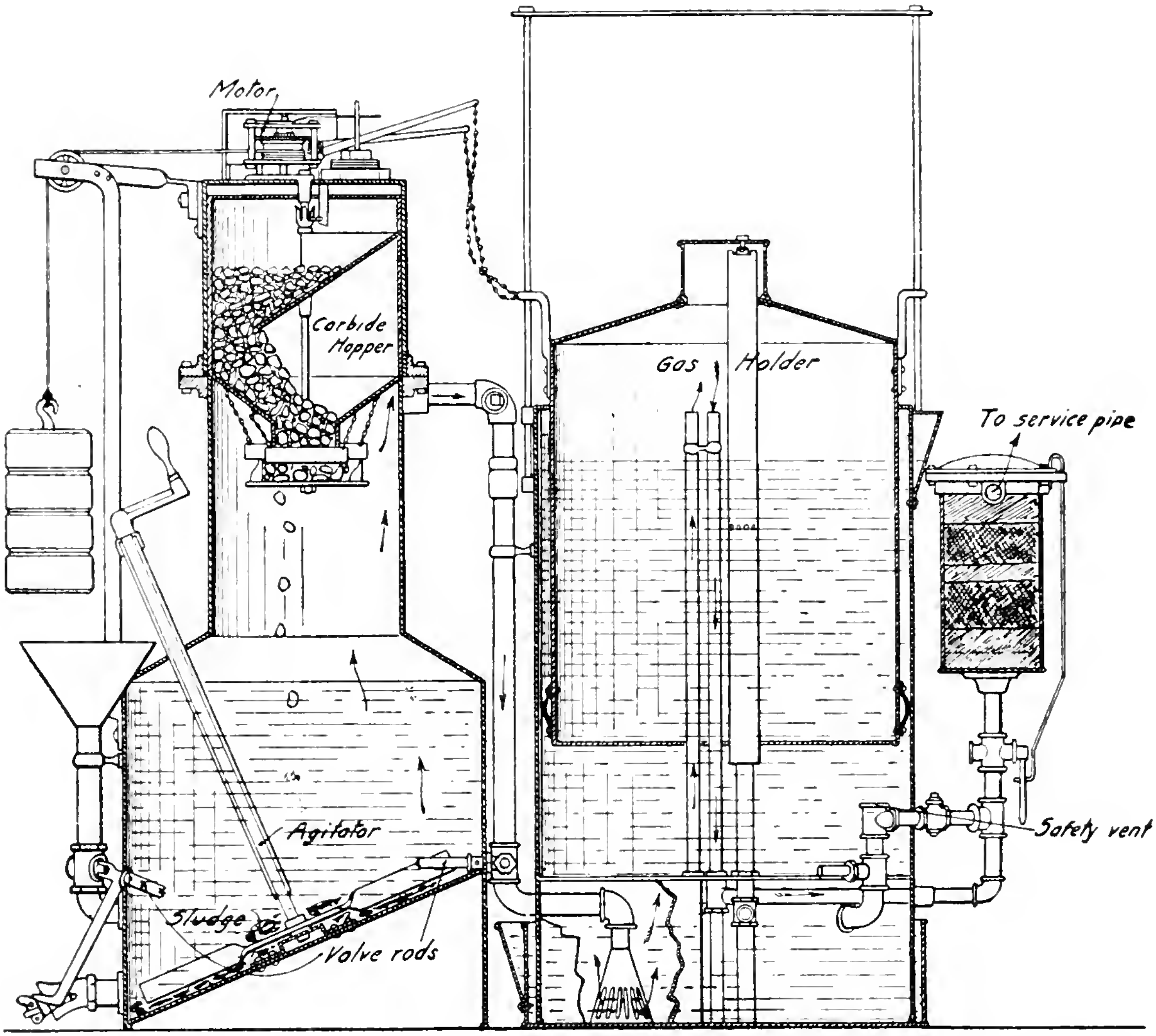
There is a system known as a *gasoline pressure-system*. In this installation a small brass tube is run through the walls of the building to the point where light is desired. Here it is brought out and put through a lamp, the special characteristic of which is a thin—usually coiled—generator tube, which must be warmed in order to gasify the oil. The gas is then delivered to the mantle. This installation is very satisfactory as to quantity and quality of light, but has this objection; it calls for gasoline pipe lines through the walls and floors of a building, at 25 to 35 pounds pressure. It is, therefore, not in high standing with the insurance companies. It is quite satisfactory for temporary buildings where the pipe lines are not necessarily covered.

Attempts have been made to use alcohol in these systems, but the cost, even when denatured alcohol is used, is sufficiently high to exclude them from the market.

Blau-gas. The next improvement in the oil-gas system is that known as *Blau-gas*. This gas is made after a process very similar to that known as *Pintsch*. This latter system has been used for railroad-coach lighting for several years. It consists, essentially, in the heating of a heavy mineral oil, known as gas oil, to a point where it becomes a permanent gas. This point is known as the *cracking-point*. After being cracked, the gas is washed or scrubbed to remove tar and other foreign matter, and is then put through a compressing process and reduced to liquid. The pressure at which it is marketed is 100 atmospheres, or about 1,500 pounds. It will immediately return to the gaseous state when released. This compressed gas is not explosive except when it is mixed with air in the proper proportion. The bottles containing the gas at the high pressure are not dangerous to handle. They may be given any ordinary rough usage without fear of accident. It is asserted that air carbureted with Blau-gas has a smaller range of explosibility than any other known gas; that is, the proportions must be in a very nearly constant quantity. Blau-gas is very high in heating power — 1,800 British thermal units per cubic foot — about three times as high as ordinary city illuminating gas. It is put up in bottles containing 20 pounds, each bottle yielding about 250 cubic feet of gas.

The plant is a very simple one, consisting of a steel cabinet with a capacity for two bottles of the liquefied gas, and a reducing-valve and expansion tank. Standard gas pipe is used through the house, and ordinary fixtures. It requires a special burner for cooking. This gas gives the best results when burned in a mantle. Since it is high in heating value, it is used to some extent for brazing in small isolated plants, such as garages, where small repair work is done. The method of handling a Blau-gas plant is to return one bottle, when emptied, to be exchanged for a full one, while the second bottle is being used.

Acetylene gas. Acetylene gas has been known on the market for a long time. There are at present several very satisfactory machines for producing and distributing this gas. The raw material, or carbide, is produced in an electric furnace from ground coke and lime, thoroughly mixed and burned together. It gives up its gas whenever it comes in contact with water, or when exposed to moist air. It is, therefore, imperative that the carbide be protected at all times from air, as this gas is highly inflammable. Acetylene gas ignites at a lower temperature than most gases, and is not explosive at ordinary pressure when contained in a vessel. It is, however, highly explosive when subjected to a pressure of 150 pounds or more. This latter fact has been a source of trouble to the manufacturers, but is now very satisfactorily overcome by the use of acetone in the compressing process. The fact that acetone will absorb many times its own volume of gas is taken advantage of; and, when so absorbed, acetylene is practically non-explosive. The most common application now to be found of this absorbed gas is seen in Presto-lite, which is used for automobile lighting. A small tank of the compressed gas is distributed through the tubes after passing through a valve. The pressure under which acetylene gas burns is very light, not exceeding 3 ounces. The heating power per cubic foot of acetylene gas is about twice that of ordinary city illuminating gas, and about two-thirds that of Blau-gas. It has a wide range of explosibility as compared with city gas and Blau-gas. However, acetylene gas may be burned without a mantle, producing a light which is admittedly nearer to sunlight than any other artificial light. It will not burn in an ordinary bat-wing burner, but requires a special burner, and burns at the



After University of Minnesota

FIG. 326. *Acetylene generator and holder, in two units. This should be installed in the basement, away from frost.*

rate of about ½ foot per hour, whereas about 3 feet of the ordinary city gas must be consumed to produce an equal intensity of light. If burned with a mantle, the city gas would produce about the same quality of light as the acetylene gas.

The acetylene plant is decidedly the most delicate of any of the plants so far considered. (See Figs. 326 and 327.) It involves a machine in which carbide may be placed. To meet the underwriters' specifications, this carbide must be allowed to drop into a chamber partly filled with water. In no case should the water be allowed to fall upon the carbide. Another detail of the plant is a holder or retainer for the gas which has been produced in the water chamber. This holder must be provided with a float, or otherwise balanced mechanism, which will set in motion the mechanism which allows the carbide to drop into the water.

This is the essential feature of an acetylene machine, for upon the precision with which this device controls the production of gas depends the safety of the machine from leakage of gas. This escaping gas is very likely to be exposed to flame and an explosion result.

A plant of this kind must be installed where there is no danger of freezing, and where there is no raw flame at any time exposed to the atmosphere around the plant; that is, it must be installed where the temperature is never below freezing; or, if the premises must be heated, the steam or hot-water plant must be placed at some distance from the acetylene apparatus.

We frequently read of the explosion of acetylene gas plants. It is very hard to get actual facts concerning one of these accidents, but it is only conservative to say that the explosions are due to carelessness in the manipulation or care of the plant; for example, when the plant has been allowed to run down and an attendant approaches after dark with a lantern, or when the quite delicate apparatus necessary for the control of the carbide-feed may have become corroded and stuck, allowing the carbide to continue the feed, with the result that more gas is produced than the holder will contain, and this gas, having leaked out into the room in which the machine is located, may reach a furnace, stove, or lighted gas jet in some other part of the house.

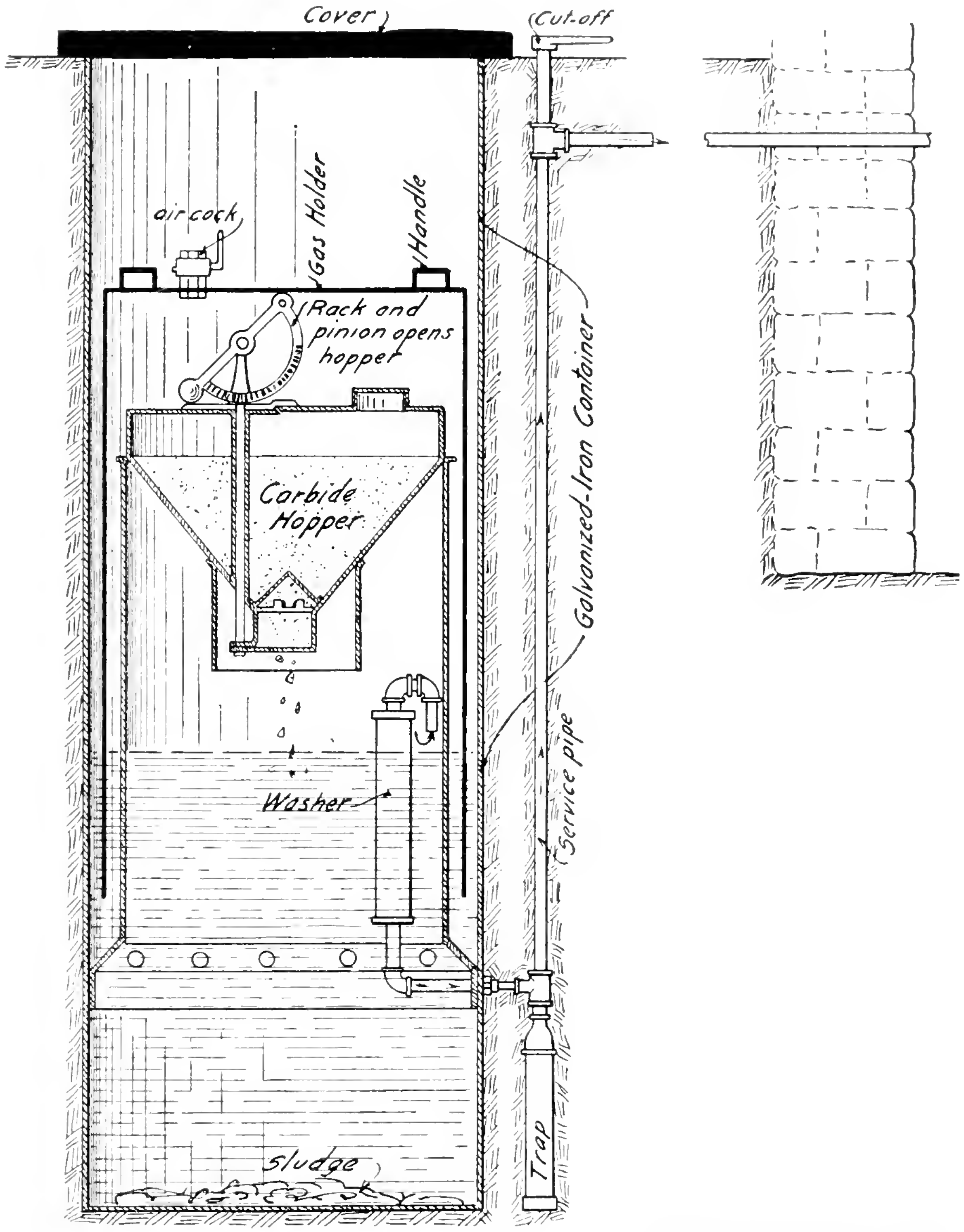


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FIG. 327. *An acetylene plant. This plant should be buried at a distance of 50 to 100 feet from the house.*

The Underwriters Laboratory, 382 Ohio Street, Chicago, Illinois, will furnish a list of manufacturers of approved acetylene or air-gas plants.

ELECTRIC LIGHT

Probably the most attractive method of illumination is by electricity. The introduction of modern high-efficiency lamps has been a great incentive to the development of small isolated electric-light plants.

Public utility service. The first question arising when a lighting system is desired is whether electrical service may be had from a neighboring town or village. If this may be had, there is little occasion for giving much thought to the isolated plant. The general service from a city or village will furnish electricity at a price which will allow its use through motors, with such efficiency that gas engines may be dispensed with on the farm. If the public service corporation cannot be induced to furnish current, it will then be necessary to consider the isolated plant, but it will not be practical to install a number of small motors which may be supplied from your own generator and storage-battery system. This latter statement is made because of the low efficiency of the low-voltage motors, there being too large a loss in transferring the energy from the generator to the storage battery and back through a motor in the low-voltage system.

Volt. To make this clear, let it be understood that a volt is the pressure which forces electricity along a conductor. It is analogous to the pounds pressure on a water pipe. The ampere is the quantity of flow through the conductor due to the voltage, resistance being an element. The ampere is analogous to the water which will flow from the end of the pipe because of the pressure, providing the pipe is not so long that the resistance overcomes the pressure. The conductor in each case may be so long that there is no flow.

Watt. A watt is a quantity which involves both the voltage and the amperage. The two multiplied together will give the watts. For instance, a 110-volt lamp consumes 3/10 of an ampere. It is therefore a 33-watt lamp. Lamps are now rated according to the wattage rather than by the candle power. Although in the medium-sized lamps very nearly one candle power will be produced for each watt consumed, in the smaller lamps—that is, in the low-voltage small lamps—the amperage is one-half higher than in the larger lamps. A thousand watts are known as 1 kilowatt; 746 watts equal 1 horse power. Therefore a 1-horse-power engine would turn a generator which would give us 746 watts, minus 5 or 10 per cent loss by heat and friction in the machine.

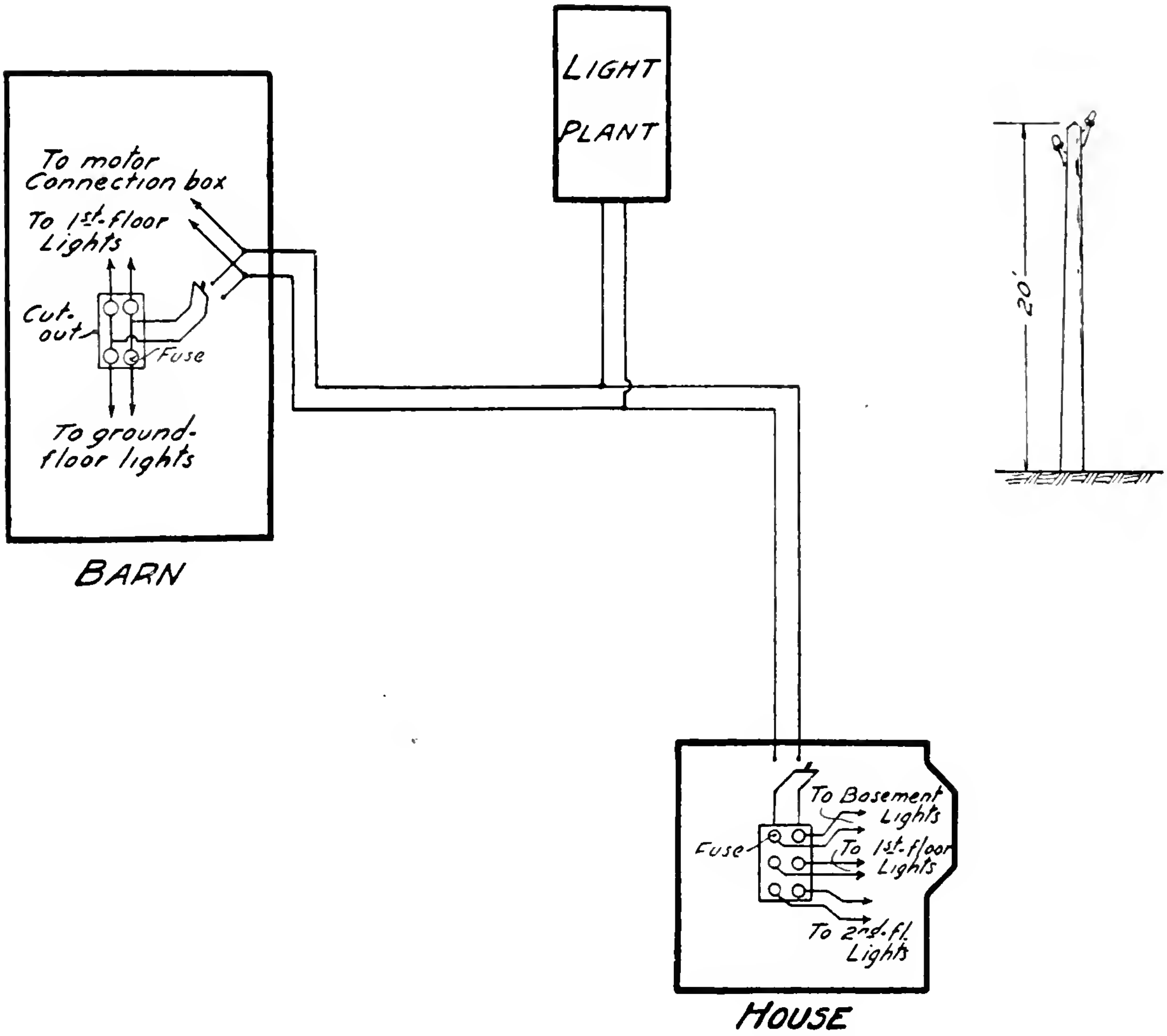

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FIG. 328. *Suggestions for wiring house and barn. Fuse-boxes and switches at each building are shown.*

Lamp hours. In the planning of an electric lighting system the number of lamp hours which will be required must be decided in order that the size of the storage battery required may be determined. Note the number of lamps and the number of hours each one is used. It is a foregone conclusion that the standard voltage of 110 cannot be maintained in the isolated plant through the medium of a storage battery, because of the cost of the storage battery. A storage cell will give about 2 volts; 55 to 60 of these would be required for the 110-volt system, and they cost from $3.50 to $4.50 per cell. It is, therefore, the practice to use a voltage of 30, requiring 16 cells. The lamps, of course, will be made for the low voltage.

Plant equipment. A system for an isolated plant will require the following articles:

1. An *engine* with 50 per cent more power than is calculated as necessary to drive the generator. A ½-kw. generator should have a 1½- or 2-h. p. engine.

2. A *generator*, of such size that it will light the whole installation; as a ½-kw., a 1-kw., or a 2-kw. generator.

3. A *storage battery*, with a number of cells larger by one than half the voltage of the system installed.

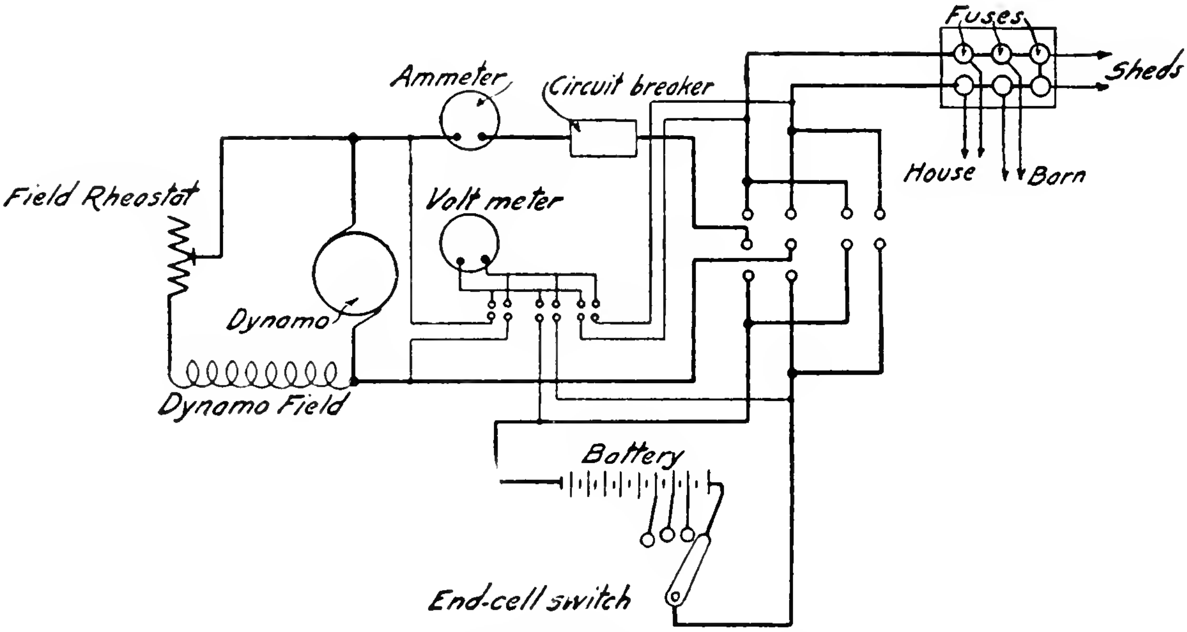

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FIG. 329. *Switchboard wiring for generator and storage-battery room*

4. A *switch board.* This may be of slate or marble, and be equipped with the following: (*a*) a rheostat, to control the

voltage of the generator; (*b*) an ammeter, to measure the amount of current; (*c*) a voltmeter, to measure the pressure;

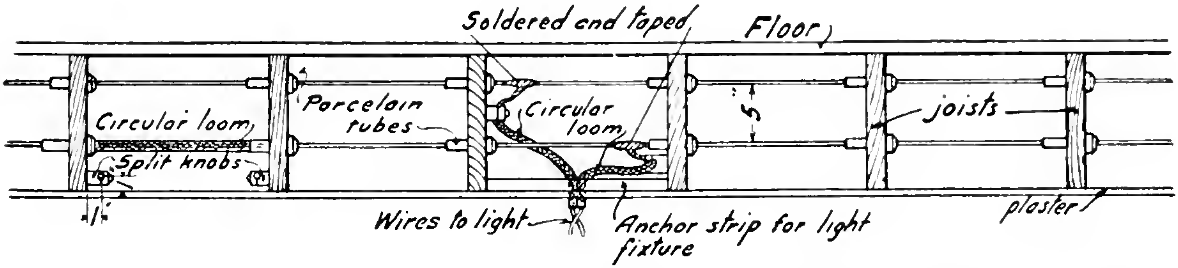

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FIG. 330. *Knob and tube installation of electric wires in joists. Extra protection where one wire crosses another and an outlet take-off through the plaster are provided.*

(*d*) a circuit-breaker, to disconnect automatically the battery or generator in case of overload or accidental reversal of direction of flow of current; (*e*) a plug switch, to admit of different connections to the voltmeter, that the voltage may be measured at several places; (*f*) two main switches, to connect the generator, battery, and lamp circuit in any desired manner. (See Fig. 329 for wiring layout on the switchboard.)

5. *Wiring.* The switchboard wire should be made of No. 8 double-braided copper wire. Through the house or inside of barns a No. 14, known as "new code" wire, should be used. The installation of this wire should be made in accordance with the underwriters' specifications as regards bushings, protection, etc. Wires between the generator and distant buildings should be No. 10 or No. 12 weather-proof. No. 12 is sufficiently large, but No. 10 is far more rugged and will stand an accident, such as the falling of a tree, or a loaded wagon passing under and dragging across the insulation, with less liability to damage than will the lighter wire.

The arrangement of lamps in the house, as well as in outbuildings, should be given careful thought. A study of the conditions will save many a desire, at least, to change the location of a lamp after it has once been installed. Three way switches will be found of very material value at one or two places in the house and at several places in the barns.

By means of these the lamps may be turned on or off at different places. They will save a good many steps and make it possible to get light when and where it is wanted.

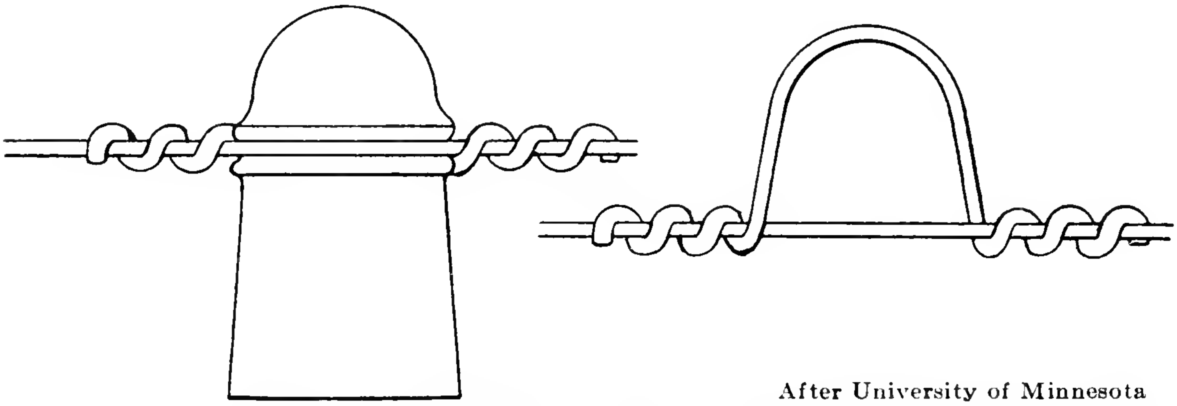
After University of Minnesota

FIG. 331. *Method of attaching feed wire to glass insulator on a pole*

Incandescent lamps. For years the carbon-filament lamp was the only kind on the market. The tantalum lamp was invented, but soon was followed by the tungsten. The latter lamp has displaced the tantalum almost entirely, and the carbon lamp is now being used only by those who have not had occasion to appreciate the higher efficiency of the tungsten lamps. Three tungsten lamps can be operated for the price of one carbon. It is therefore folly to buy new carbon lamps, and it is a question whether you can afford to burn your old carbon lamps as an attempt at economy, except where a lamp is used very, very little, as, for instance, in the attic. The nitrogen tungsten further increases the efficiency of the lamps.

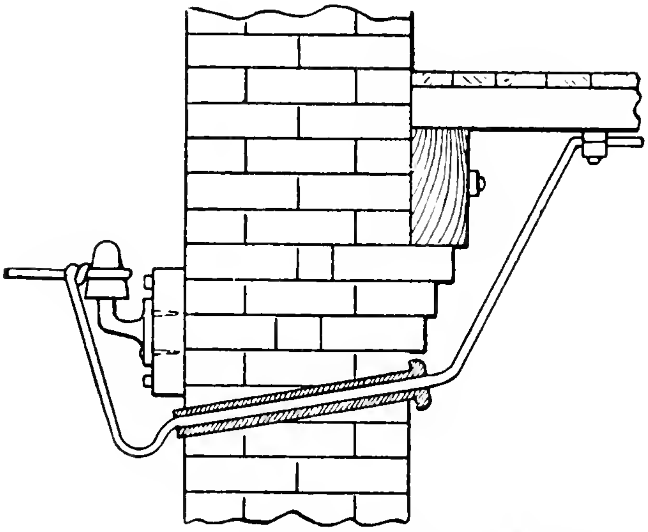
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FIG. 332. *Method of entering a building to prevent water from following the wire through*

SUMMARY

If it is desirable to install an isolated lighting plant, it is important to recognize in advance the fact that if the plant is to be a success after installation vigilance must be untiringly exercised. The isolated lighting plant is not a plaything, nor is it a piece of machinery made for every chance user. A perfectly working acetylene-gas system is a delicate piece of machinery. The electric lighting plant, completely equipped with an ample storage battery, is even more delicate than the gas plant.

In the city we find many people using electric lights, electric toasters, electric washing machines, electric irons, and electric vacuum cleaners. These are costing a good many dollars more than they should in the yearly expense of maintenance because of the lack of understanding on the part of the users which necessitates the employment of expert service extending over months and sometimes years. The people in the city can get the service if they are willing to pay for it, but people in the country cannot buy it, even though they have the money. Instead of telephoning in and getting help in half an hour, they may have to wait days for it to reach them. In the meantime they are without the convenience of their installation.

The man who puts in the isolated lighting plant, of whatever variety, should understand the plant thoroughly, and make up his mind to have it on his list, along with the pigs and the calves and the chickens, to receive its share of persistent attention.

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CHAPTER XXI

LIGHTNING RODS

Lightning flash. There are few persons of the present day who are not familiar with electric currents and who have not seen an electric spark or the flash which occurs when an object is brought close to another which is charged with electricity. The visible spark is not the electric current, but white-hot air resulting from the resistance of the air to the passage of the current. The presence of the current is indicated by a snapping sound and by this light. Scientists have proved that a lightning flash is due to the heating of the air by the passage of an electric current through it and that practically the same thing is taking place between two clouds or between a cloud and the earth that takes place between the poles of an electric machine when a spark jumps from one to the other. The earth is charged with negative electricity, and the clouds become charged usually with positive electricity, but occasionally with negative. When the accumulation becomes sufficiently strong, a current will pass to another cloud or to the earth.

Damage by lightning. The harm from a lightning flash comes from the current itself and may cause death to animals, set fire to inflammable materials, or melt fusible materials in exactly the same way that a strong current from a dynamo will when an animal or object becomes connected in the circuit. The cause of the generation of electricity in the air has never been clearly or definitely explained, but the effects indicate its presence, and, since loss of life and destruction of property are caused by lightning, more or less attention has been given to methods of protection from these natural electric currents.

Greatest damage from lightning occurs in agricultural communities and localities where there are few high trees and improvements projecting into the air or extending to any great depth into the earth. As good connections between the moist earth and the cloud are not available, the charge accumulates in the cloud until a discharge is necessary, when it passes through the nearest and least resistant object. The greater the resistance that is offered by the object through which the current is passing, the more damage will be done by the current. Where there are suitable conductors and enough of them, the electric current is equalized by a continuous flow from the cloud to the earth, and dangerous accumulations are thus prevented. It has been observed that lightning seldom strikes in cities and that metal objects such as locomotives and steel ships are apparently immune. Smoke stacks, high buildings with steel frames, wiring systems, etc., of the city, are projecting into the air as well as deep into the ground and offer an easy route for the current. As a result, the equilibrium between the earth and the cloud is maintained and damaging lightning strokes do not occur.

When an animal or a building is in the path of the lightning, death or fire is likely to be the result. Since water offers less resistance than dry earth, the current will tend to pass through an object that leads into moist earth, and as warm air offers less resistance than cold air, there is a tendency for the current to follow the warm air. This may account for the fact that animals are frequently killed in an open pasture, because during a storm they have a tendency to crowd close together and their bodies warm the air above them. Animals are also killed when standing close to a wire fence. The current is carried on the fence and passes through the body of the animal in reaching the ground. The dangers of lightning stroke are materially reduced when the rain begins to fall, because each drop comes to earth with a charge which assists the neutralizing of the stress between the cloud and the earth.

Theory of lightning rods. The theory of lightning rods is based on the principle that to protect buildings from lightning stroke it is necessary to make an easy path for the current from the highest point on the building into the moist earth. Experience has shown that some of the conditions which were supposed to be essential when lightning rods were first invented are not necessary. At one time the metal conductors were insulated from the building by the use of glass in an effort to keep the entire lightning-rod system from coming into contact with any part of the building. It has been proved that this is a mistaken idea and that the object of the lightning rod is to maintain connection between the building and the moist earth and to carry away the electric current as rapidly as it may accumulate in any part of the building, as well as to take it direct from the air.

Material. The material used for conductors should be a substance which will offer a minimum resistance to the passage of the current and will not be destroyed by rust or corrosion. At the present time two materials are used: copper and galvanized iron. Copper is the better conductor and does not readily deteriorate from the action of the elements, but it may cause side-flashes and is quite expensive. Iron offers greater resistance to the current, but is much cheaper and is preferred to copper by some authorities. When it is galvanized or protected by a coat of aluminum paint, its durability is satisfactory. Where copper is used, the conductor is usually made of woven copper fabric rather than a rod, because greater conductivity can be secured by the use of the fabric than if the same weight of metal is used as a rod. If the conductor is small, there is danger of its being melted by the current. The larger it is, the greater the expense becomes, the cost being the only objection to a large conductor. The conductive qualities of different fabricated forms of the same metal can be determined by the weighing of equal lengths. The heavier contains more metal in a given length and is the better conductor of the two.

Installation of a lightning-rod system. One of the most important features in a lightning-rod system is to have the lower end of the conductor placed so deep in the ground that it is always in moist earth. The upper end should be a point and should extend approximately 30 inches above the highest point of the building. Points should be well plated or galvanized so that they will not rust and become blunt. The cupola of the barn, the chimney of the house, and the top of the silo should be protected by points. The conductors should be fastened directly to the building with either metal staples or wooden cleats and should have a metallic connection with the eave spouts, door hangers, metal ventilators, hay carriers, and all other metal parts of the building. For small buildings two conductors passing into the ground at diagonal corners of the building are sufficient. Larger buildings should have three, and the largest of farm buildings should have four. The third and fourth ground conductors should be so placed that they will collect and carry their proper proportion of the current. Ground conductors should enter the ground under the downspout, or, if there are no downspouts, under the eave-drip, the object being to get them into the ground where there will

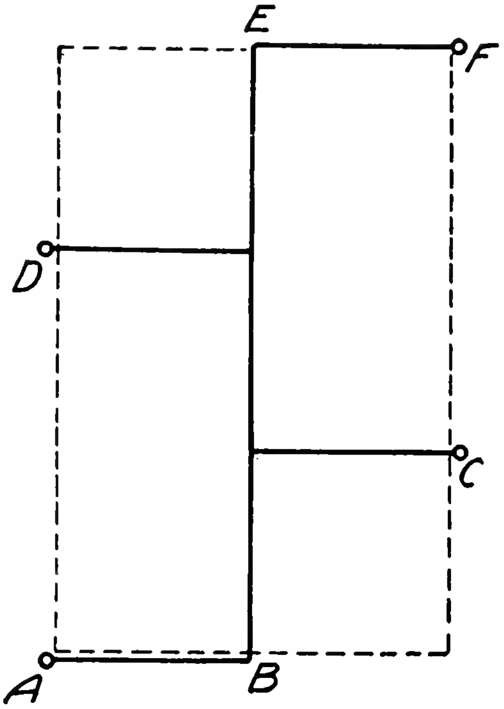

FIG. 333. *Showing position of the ground wires on a building. When the line B–E does not exceed 30 feet, ground wires at A and F are sufficient. When B–E is greater than 30 feet, grounding at either D or C should be installed at a point halfway between B and E. When B–E is greater than 60 feet, the ground wires A, C, D, and F should be installed as shown in the figure. B–E represents the length of the ridge of the building. A and F are opposite diagonal corners. An L-shape building should have three ground wires and a square building either two or four.*

be a maximum quantity of moisture and where the ground becomes moist early in the storm. Steel windmill towers should be grounded by wires fastened to the lower part of the tower and buried in the moist earth.

Because of varying soil conditions, no specific depth can be given. There is no danger from excessive depth, and many lightning-rod systems have been failures because of shallow grounding. Eight or ten feet is an advisable depth under nearly all conditions. One hundred to two hundred pounds of scrap iron buried in a large hole around the ground conductor is desirable. Occasionally where digging is hard a trench is dug and filled with scrap iron placed around and in close contact with the ground conductor. Some authorities recommend extending the ground conductor into a well.

Detailed instructions relating to wiring a building for protection from lightning are covered by Alfred J. Henry in *Farmers' Bulletin 367*, U. S. Department of Agriculture.

SUMMARY

No better conclusion can be drawn for this chapter than that given by Professor S. C. Lee of the Manitoba Agricultural College, in *Extension Bulletin No. 1*, after an elaborate series of experiments to determine the efficiency of lightning rods

Copper and galvanized iron are the standard materials used for lightning conductors. Conductors of sufficient size to carry the heavy lightning currents should weigh at least 3 ounces per foot when made of copper and 5 ounces per foot when made of galvanized iron.

Any shape of cable that is desirable and easily put up may be used. Cable made of twisted strands of either iron or copper is very suitable.

All parts of the wiring should be connected into one system and no blunt ends or stubs left ungrounded. Where joints must be made, they should be very secure, and connections should be made as perfect as possible by soldering, brazing, or welding.

Points should be placed 3 feet from the end of the ridge, and others should not be more than 20 feet distant, with one on each chimney, cupola, or other high place.

Wire fences should be grounded every 15 rods by means of a No. 9 wire stapled along the post in contact with each line wire and extending 3 feet into the ground.

Metal roofs should be grounded from the lowest point at two or four corners. If the building sides are metallic, ground the lowest part of the sides at the corners. Eave troughs, roof gutters, hayfork tracks, etc., should be connected with the ground cable.

Periodic inspection of the wire should be made to see that all parts are in good condition. Necessary repairs should be made at once.

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CHAPTER XXII

TELEPHONES

Invention. In the year 1875 Alexander Graham Bell made a discovery which led to the electrical transmission of speech. While carrying on experiments with a view to developing an improved system of telegraphy, he observed that a thin strip of iron could be caused to vibrate if supported with its free end in proximity to one of the poles of an electromagnet, the winding of the electromagnet being connected to another and similar one, having associated with it an iron reed which could be set in motion by hand.

From this beginning it was but a short step indeed to the development of devices which had diaphragms instead of reeds, and permanent magnets instead of electromagnets, which would transmit articulate speech. Such devices were exhibited at the Centennial Exposition in Philadelphia in 1876. The telephone receivers in use today are essentially the same as those early "telephones."

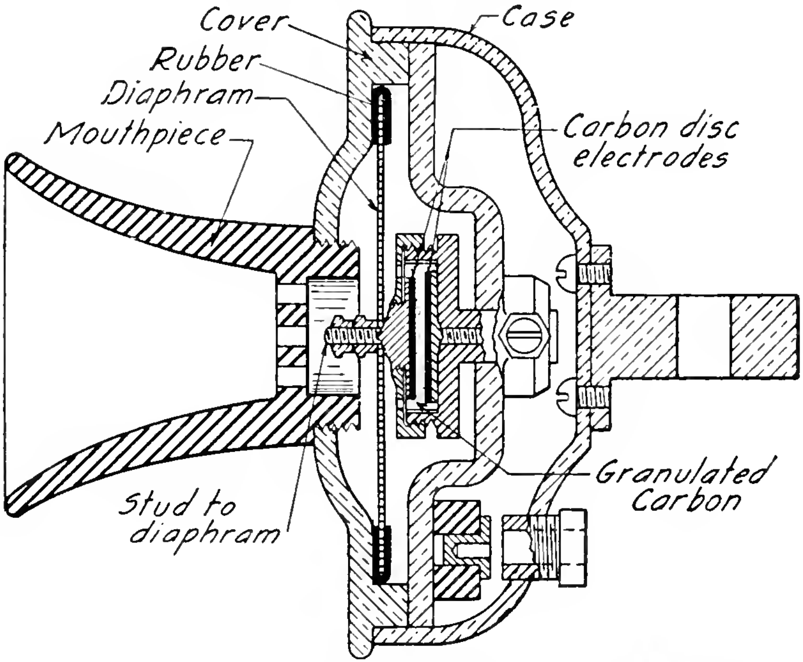

FIG. 334. *Typical receiver as used on induction coil circuits.*

Transmitters. Quite early in the course of experimental work on the telephone it became apparent that a better method of generating the telephonic or voice currents would be necessary, because the currents produced by the simple telephones were so feeble that the range of possible operation was very much restricted. This line of investigation had its inception in the fact that the investigators who were experimenting with the first telephones observed that movements of the connections in the conductors forming the circuits produced sounds in the telephones.

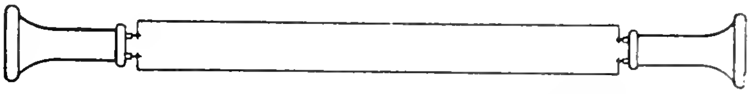

FIG. 335. *The simplest possible telephone system. The current is produced by inductive effect only.*

Various substances were used in the experiments, and it was found that, while conducting bodies generally, when in loose contact, would vary the resistance in a circuit when subjected to the vibration of a diaphragm caused by sound waves set up by audible speech, carbon was most positive and uniform in its performance in this regard.

Carbon transmitters of many designs have been produced. The single-contact Blake transmitter was in very general use a few years ago. Several forms of multiple-contact transmitters employing carbon pencils or carbon balls were used to some extent. The type most popular at present is the granular carbon type, of which the White solid back is a good example.

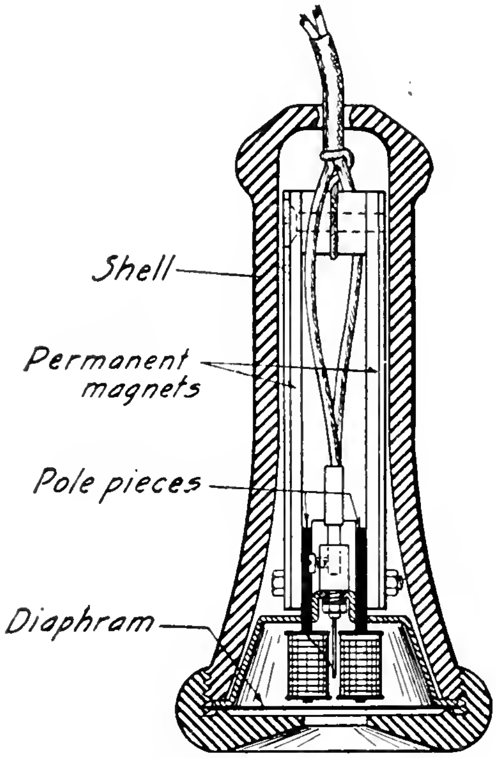

FIG. 336. *Showing details of transmitter construction*

Series circuit. The transmitters and receivers of a telephone circuit may be placed directly in series with the battery and satisfactory results may be obtained where the lines are short, but when the receivers and transmitters are so connected, the receiver must be so constructed as to offer the least possible resistance to the battery current as well as the voice currents. For this reason some of them are known as direct-current receivers. In these the permanent magnets have been eliminated and the necessary magnetism is derived from the batteries through the effect of the current on the winding of the receiver magnets. Since a transmitter is essentially an instrument for varying the resistance of a circuit, its effectiveness is dependent upon the extent to which it can vary the resistance in that circuit. For example, a circuit containing two transmitters, two receivers, a battery, and half a mile of wire will measure approximately 200 ohms. The internal resistance of a transmitter in operation will vary from 5 to 50 ohms, a net variation of 45 ohms. This is 22½ per cent of the total resistance of the circuit. Now suppose the length of line is increased until the total resistance of the circuit reaches 1,000 ohms. Either transmitter will be able to vary the resistance of such a line only 4½ per cent. Since the volume of sound reproduced by the receiver is dependent upon the changes occurring in the current flowing through its winding, it will be apparent that, even though the voltage of the battery is such as to cause the same amperage to flow in the circuit in both cases, the volume of sound which can be produced under the second condition assumed would be materially smaller than it would be with the shorter line.

Other considerations which have a bearing on the foregoing and which will assist one in grasping the limitations of the series circuit are: (1) It is not possible to increase the volume of transmission by increasing the current through the transmitter, thus compensating for increases in lengths of lines. (2) The parts of the instruments as at present designed and constructed for resistance variations such as those cited will withstand only a rather definitely limited amount of current without overheating

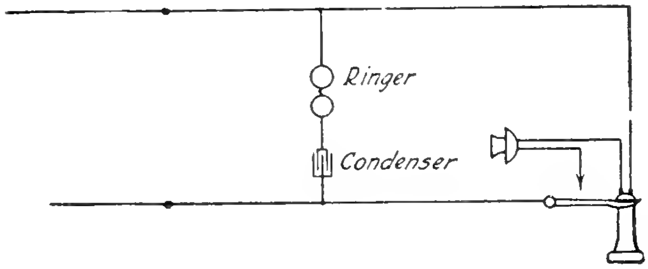

FIG. 337. *Circuit for common battery series telephone used on lines up to two miles*

and permanent injury. (3) To increase the sizes of the current-carrying parts is not feasible, since their size and weight must be kept within rather well-established limits, to insure that their inertia and natural periods of vibrations will be such that the instrument will faithfully react under the influence of the sound waves impressed upon them.

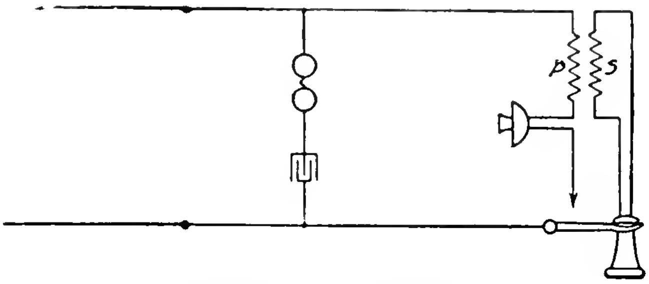

FIG. 338. *Circuits for common battery induction coil telephone*

It was found that to establish telephonic connection between any two telephones in the same system, the telephone instruments must be universal in order that they may be used for conversation over lines of practically any length.

Induction coil circuit. To extend the range of the battery transmitter and receiver combination, the induction coil is utilized principally in telephones of the local battery or magneto type, where the transmitter current is supplied by a battery individual to each instrument.

Call bells. To complete the telephone instrument, it was necessary to find some form of electrically operated device which would produce a signal sufficiently loud to call the attention of persons in the vicinity of a telephone instrument to the fact that some one desired to communicate with them. At first, when the lines were short, an ordinary vibrating doorbell gave satisfactory service, but as the lines were extended it was necessary to use the telegraph for signaling purposes. Although efficient, the telegraph was too expensive and cumbersome for extensive telephone systems, and further experiments were made to obtain a satisfactory signaling device for

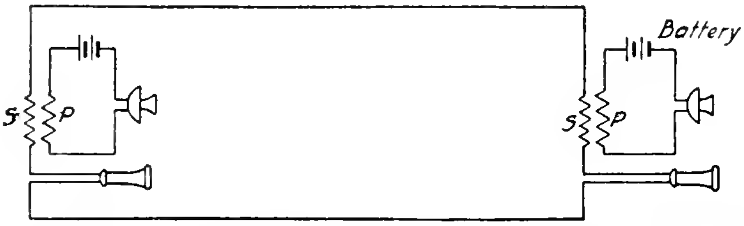

FIG. 339. *Induction coil local battery stations using metallic circuit*

telephones. It was found that a call bell of a type which will respond to an alternating or pulsating current of relatively low frequency was admirably suited to the purpose, and such bells are now in quite general use in telephone practice.

To provide the necessary alternating current for operating the bells and the signals at the central offices in local battery systems, a small dynamo electric machine similar to those which are in common use in electric-light and power plants, except that permanent magnets are used for the fields, was found to be effective. This device is operated by a crank protruding through the right side of the instrument, called the *magneto*.

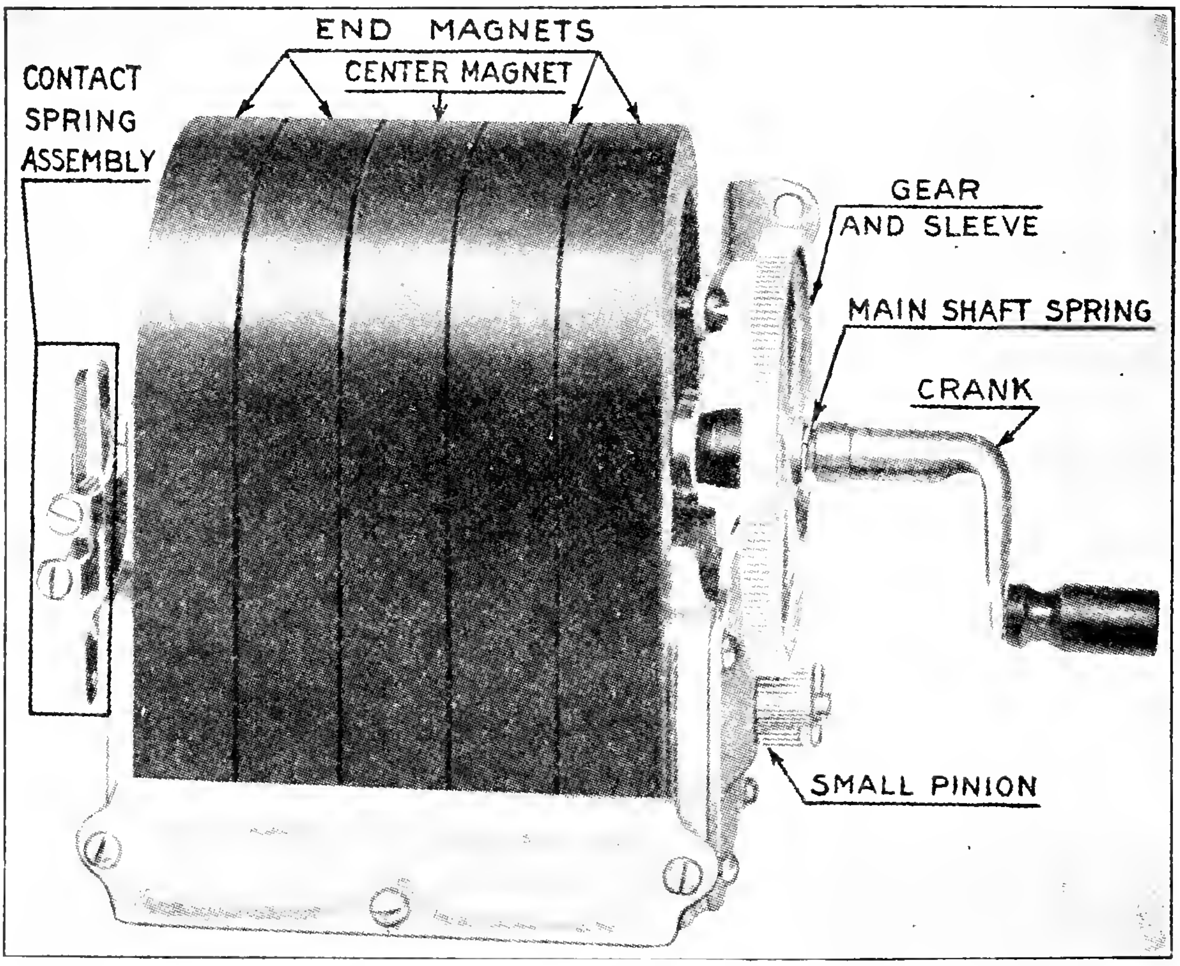

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FIG. 340. *Magneto or generator as used in local battery stations*

A form of switching device was needed for changing the connections of the line conductors from the signaling device or bell to the talking devices. The hook switch, which is an essential element of most telephones in common use, was devised, and when the elements so far described are combined the "local battery telephone," with which most people in the United States are familiar, is obtained.

Telephone system. Two such telephones, when connected by a pair of wires, or by a single wire and the earth, provide facilities for communicating between the points where the instruments are located.

Most of the telephones in use at the present time form parts of telephone-exchange systems, facilities being provided at the central offices for connecting each telephone with others in the system.

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FIG. 341. *Common battery wall set*

For telephone-exchange service in cities and towns it has been found to be possible and desirable to concentrate the battery supply for the transmitters and the current supply for operating the bells at the central office. Also, it is the practice to arrange the signals which are employed for attracting the attention of the operators at the central office so that they are responsive to the movements of the hook switch in the telephone set. The telephone instruments employed in such systems are similar to the local battery instruments except that magnetos

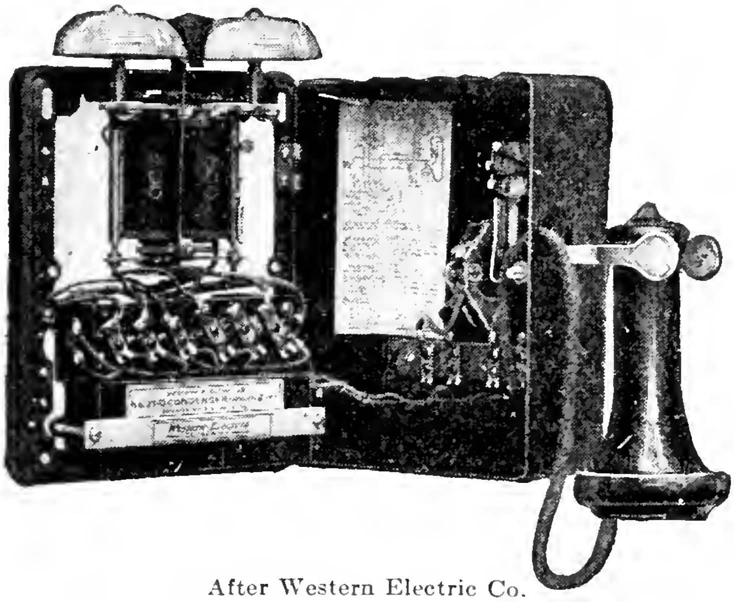

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FIG. 342. *Same as Fig. 341, open*

are not used, batteries are not associated with each telephone, the transmitter and the primary of the induction coil are connected in the line, the receiver and the induction coil secondary form a local circuit, and, usually, a device known as a *condenser* is placed in series with the bell. The condenser is used for preventing a continuous flow of direct current from the central office through the windings of the bells, which, in addition to being wasteful, would complicate the operation of the central-office signals. The condenser also aids in augmenting or boosting the voice currents by increasing the range of voltage variation.

The particular system of exchange or switchboard service referred to herein is what is known as the *manual type*. Other systems are known as intercommunicating, semimechanical, and mechanical or automatic. The intercommunicating and automatic systems involve other switching apparatus in addition to that described as a part of the telephone instrument.

Rural lines. If it is desired to provide telephone service for a user or for a group of users in any locality, it is desirable first to ascertain what facilities have been established by the telephone company or companies operating in the locality for caring for the needs of the people in the neighborhood. If the prospective users are in or near the corporate limits of a city or village having exchange service, it will usually be best to obtain telephone service from an established telephone company offering service to patrons on a rental basis. If the prospective users are on or near an established toll line or interurban route of an established company, it may be found that, all things considered, the telephone company can provide the desired service more economically than can an individual user or a group of users acting for themselves. If it is found that the construction of a line offers the most satisfactory means of obtaining telephone service, the matter of making arrangements with the telephone company or companies for exchange and toll-line service should receive consideration, because a telephone line without exchange and toll-line facilities is like a railroad without terminal facilities, if such a thing can be imagined, and will not be a real success.

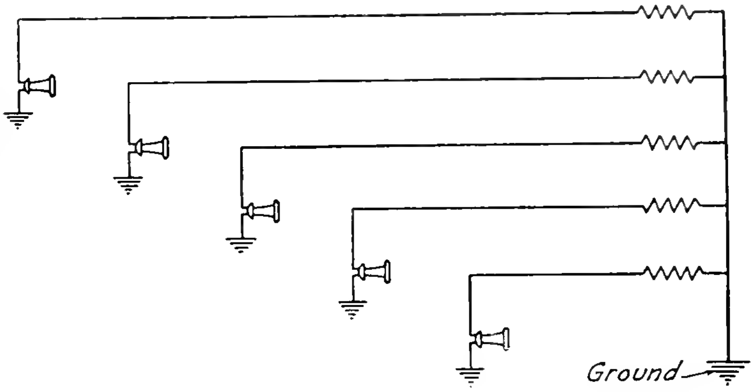

FIG. 343. *Grounded private-line system*

Other things to be determined through negotiations with the telephone company, in case it is decided to build a telephone line, are those which have a bearing on the type of circuit to construct and equip, to the end that it may operate properly with the apparatus, and under the operating method of the telephone company. Some of those things are: (1) whether central battery or local battery service should be arranged for; (2) whether party-line service can be handled by the telephone company, and, if it can, the kind of party line service which is arranged for (a party line is one having more than one telephone connected to it); (3) whether the line or lines constructed should be metallic or "ground" circuits (a metallic circuit is one consisting of two wires, and a ground circuit is one consisting of a single wire, the earth being used as a return).

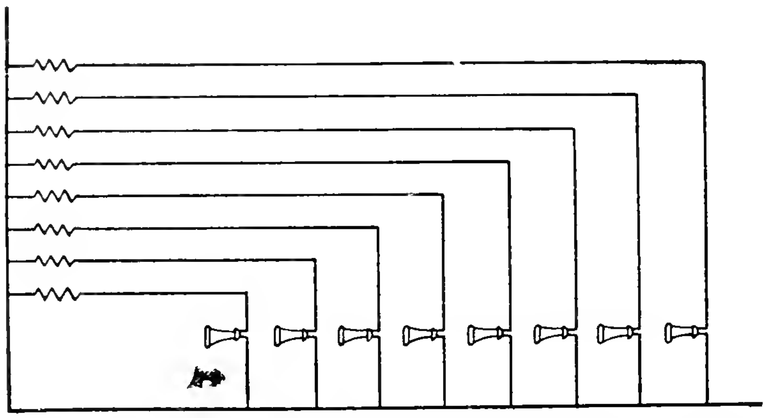

FIG. 344. *Private lines using common return wire (McClurg system)*

Exchange service. As to the first point, some telephone companies having central battery systems in town plan to operate all telephones within a certain distance (ten miles from the central office) on a central battery basis. Others offer either central or local battery connections, considering each case separately, while many offer local battery connections only. Still another arrangement provides central battery for signaling the central office, and local battery for all talking.

Where central battery is provided, either for signaling the central office or for this purpose and talking as well, a desirable feature is obtained in that calls for the central office from any station on the line do not operate other bells if there are other stations connected to the line. On the other hand, one station cannot call another on the same line except by signaling the central office and having the desired second station on the same line signaled from that point. Where local battery is employed, it is possible for any station to call any other on the same line, except where specially constructed telephones are used for the purpose of insuring that all calls shall be supervised by the central office. Such telephones have direct-current generators, and their bells, being responsive to alternating current only, do not operate when the generator is turned, but the signal at the central office does, as it is designed to respond to direct current.

Still another type of local battery instrument, which is sometimes used on metallic circuits, is one provided with a key or switch by means of which the generator, which is of the alternating-current type, can be connected either across the line, when it will operate the bells on the line, or between the wires of the line and ground, when it will operate the central-office signal, leaving the bells at the various stations silent. It will be seen, therefore, that the exact type of instrument selected must depend upon the facilities contained in the switchboard at the central office for terminating circuits of the kind under consideration.

Party lines. Regarding the second point, that of party-line service, the telephone company should be consulted, and its facilities should be taken into account in the selection of instruments (telephones) and the construction of the line.

The party-line system in most common use is what is known as the bridging-bell system, so called because all bells are connected to the line in multiple and thus form bridges over which current can pass from one side of the line to the other.

Bells of relatively high resistance, 1,000 to 2,500 ohms, must be used for bridging party lines, since if the bells are not of high resistance a large portion of the voice current will pass through them, and poor transmission will result. Furthermore, uniform signaling cannot be obtained without the use of such resistance bells, because if low-resistance bells were used on bridging circuits the one nearest to the calling station would consume an undue portion of the signaling current, and those at a distance would ring feebly or not at all.

For calling the various stations systems of signals consisting of varying numbers of rings or of combinations of short and long rings are used on party lines such as just described. This system of signaling is known as the code-ringing system. There is no very definite limit to the number of stations which can be connected to one line, but it must be kept in mind that all of the bells respond to every signal, and that, in addition to the annoyance to the persons who must hear all of the signals, whether for their station or not, many mistakes are made where the stations and signals are numerous. The number of stations connected to one line should, therefore, be restricted. For city exchange service the number is usually limited to four, and on rural party lines double this number would be a good limit. Rural lines have been reported with thirty connected stations.

A battery is good for only a limited number of talking minutes. With local battery instruments, it should be remembered that the battery circuit is closed while one is "listening in" as well as when one is talking. Furthermore, entering the circuit offers a leak for the voice currents of those talking.

Selective signals. There are party-line systems known as *selective systems*, wherein any station may be called without the knowledge of the others. Those which are in most common use are the split alternating-current system, the harmonic system, and the polarity system.

In the *split alternating-current system* one bell is connected between each branch of a metallic circuit and the earth. It is thus limited to two-party service on metallic lines.

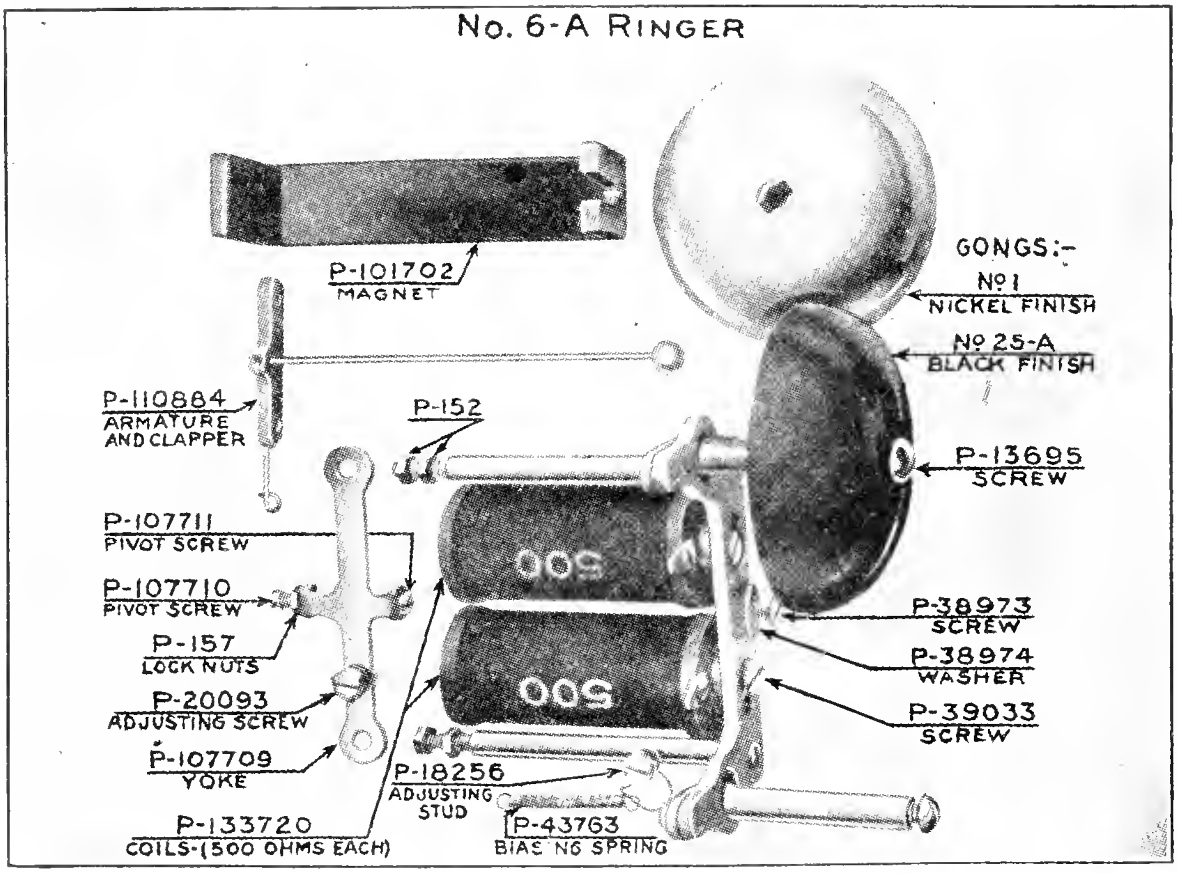

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FIG. 345. *A polarized or biased ringer*

In the *harmonic system* the bells used are so constructed that they will respond to definite frequencies. Four frequencies are customarily employed, and each bell used is so designed that it will respond to only one of the four frequencies. With this system four stations can be handled selectively if the bells are bridged across the circuit, and if they are connected between the branches of a metallic circuit and the earth, one for each frequency on each side, eight stations can be handled selectively. Since it is necessary to have four frequencies of alternating current which are not subject to variation, it is practically imperative that the use of this system be restricted to lines terminating in a central office, where the necessary machinery for producing the required current may be maintained, and that all stations be rung from the central office.

The *polarity system* involves the use of bells so designed and constructed that they will respond to pulsating or interrupted currents of one polarity only. It is in quite general use for four-party selective service on metallic circuits, a bell responsive to each polarity being connected between each side of the line and the earth. This system, like the harmonic system, is practically confined to lines terminating in central offices, owing to the somewhat involved nature of the requirements for signaling currents. It is also necessary with this system to have the central office call all stations on the lines.

In some instances semi-selective service is rendered by means of two stations connected in the same electrical relation to the line as each one in the systems just described. The users of one of the two identically connected stations are then directed to answer one ring and to disregard two rings, while the users of the other are directed to respond to two rings and to disregard one ring. This method is resorted to where it is desired to accommodate more stations on a line than can be handled in the strictly selective manner, and still to derive some of the benefits of this system.

Line circuits. The question of the type of circuit to construct, whether ground or metallic, does not depend so much on the type of apparatus in use in the central office as on the energy supply and the type of party-line service. A metallic circuit is to be recommended in all cases, owing to its freedom from cross talk and other forms of inductive as well as atmospheric disturbances. Even though the switchboard on which it is desired to terminate a privately owned line is not constructed for handling metallic circuit lines, it would be possible to provide apparatus at the central office for

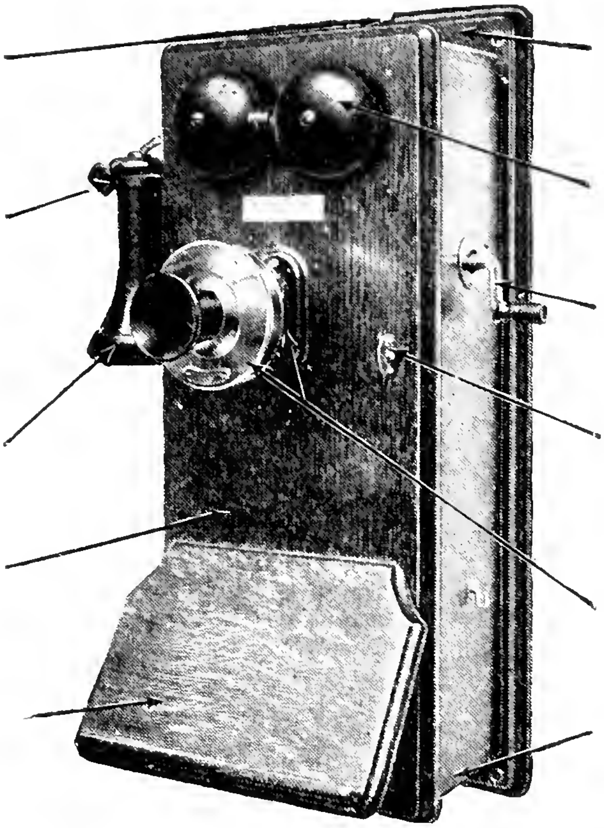

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FIG. 346. *Magneto telephone complete*

adapting the metallic line to the ground-circuit switchboard. This apparatus would be restricted to the line in question, and no extensive changes in the switchboard would be necessary.

The terms offered by the telephone companies for exchange service for privately owned lines vary considerably. In general, it may be said that the operating companies can arrange to supply whatever is necessary in the way of service (toll and local), supplies, inspections, and repairs.

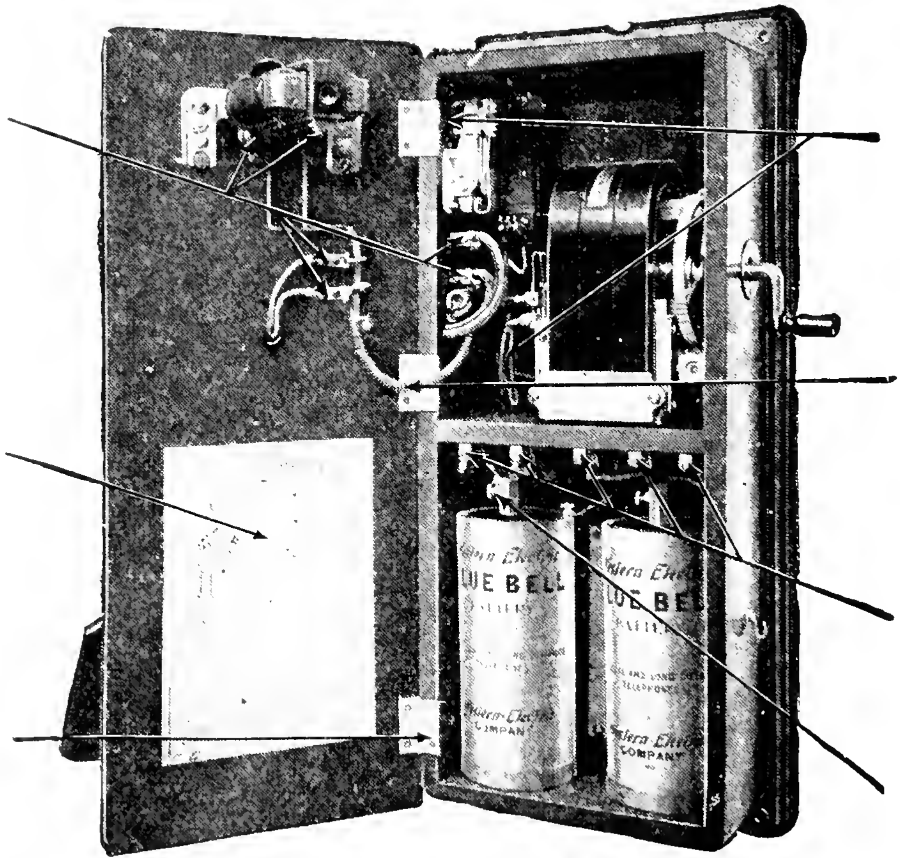

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FIG. 347. *Same as Fig. 346, open*

Line construction. The kind and size of wire to be used for the line will depend upon the length of line, the system of battery supply, the number of stations, and the system of signaling. It will usually be found, however, that satisfactory private lines can be constructed by use of No. 12 BWG iron wire for lines up to ten miles in length, and No. 9 BWG iron wire for lines up to twenty-five miles in length. A competent telephone engineer can advantageously be called in for the consideration of this question. A good grade of galvanizing should be insisted upon.

A test for galvanizing is as follows: Prepare a saturated solution of copper sulphate. Dip a sample of the galvanized wire to be tested into this solution, and leave it for one minute, then take the sample out and wipe it clean. Repeat these operations four times. If the sample has a copper color, the galvanizing is too thin and the material should not be considered acceptable for telephone line wire. If it is black in color, it is satisfactory.

As to supports for the line wire, wood poles are recommended. They may be of cedar, chestnut, pine, tamarack, or cypress. They should be not less than 5 inches in diameter at the top, and should be of sufficient length to insure supporting the wires the height required by the regulations of the governing bodies having jurisdiction over any of the territory through which the line passes. Outside the limits of incorporated villages, 20-foot and 22-foot poles are frequently used. Thirty-two poles to the mile is considered good practice.

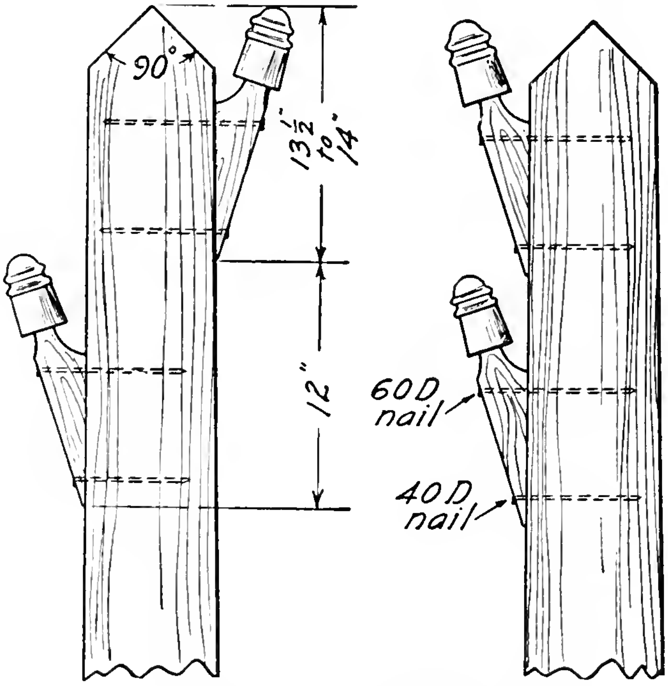


FIG. 348. *Pole with brackets*

Poles are usually set in the ground one-fifth of their length. They should be treated with a preservative at the butt end to a point which will be a foot above the ground when the poles are set. The bulletins of the United States Department of Agriculture should be consulted regarding the selection and use of preservatives.

An essential feature of pole setting is that of tamping the earth about the pole as the earth is being replaced in the holes. If it is not tamped thoroughly, it will settle unevenly and throw the poles out of alignment.

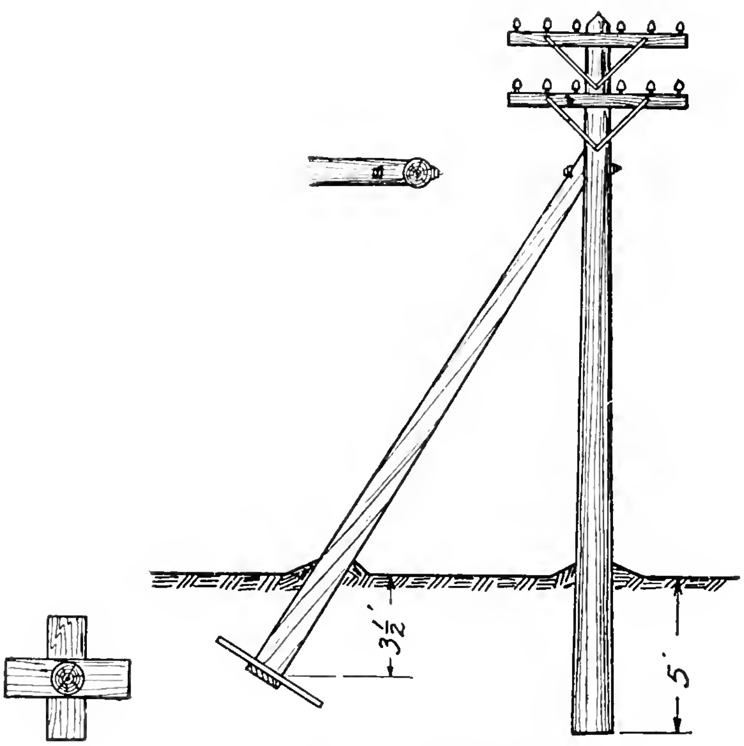


FIG. 349. *Braced pole*

On sharp curves and at corners the poles should be guyed

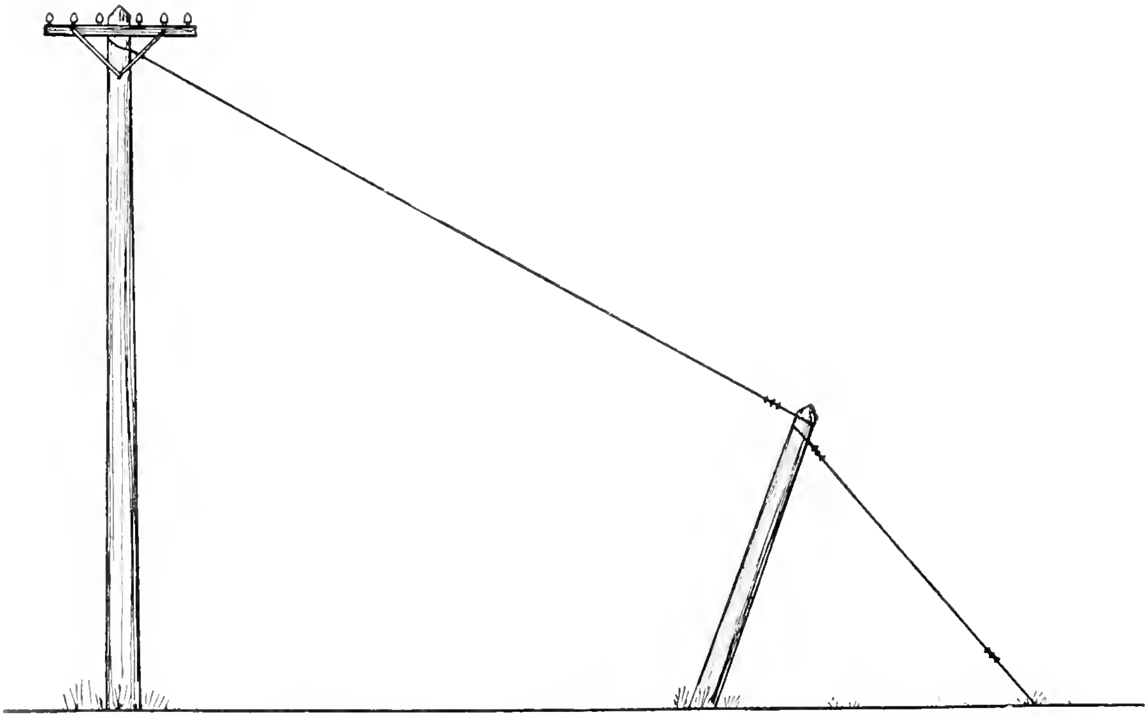


FIG. 350. *Anchored pole with stub to carry guy wire over a road*

or braced to insure that they will not "give" and permit the wires to become slack. This should be done before the wires are attached to the poles, for if it is left until the line wires are pulled taut, it will be found that some of the poles will have been drawn out of alignment, and it will be too late to correct this, since the tight line wires will hold them in the positions they have taken. For bracing, poles somewhat shorter and lighter than those supporting the line wires are employed. The brace is set into the ground at the lower end, and the upper end is shaped to fit the pole, then attached to it by means of bolts or lag screws. Guys consist of anchors buried in the ground, and fastened to line poles at a point near to where the line wires are attached, by means of galvanized strand wire. An anchor usually consists of a piece of timber with a long galvanized eye bolt through its center. The timber is buried in the ground with the eye of the bolt projecting above the surface of the ground. The end of the guy wire is passed through this eye and drawn taut.

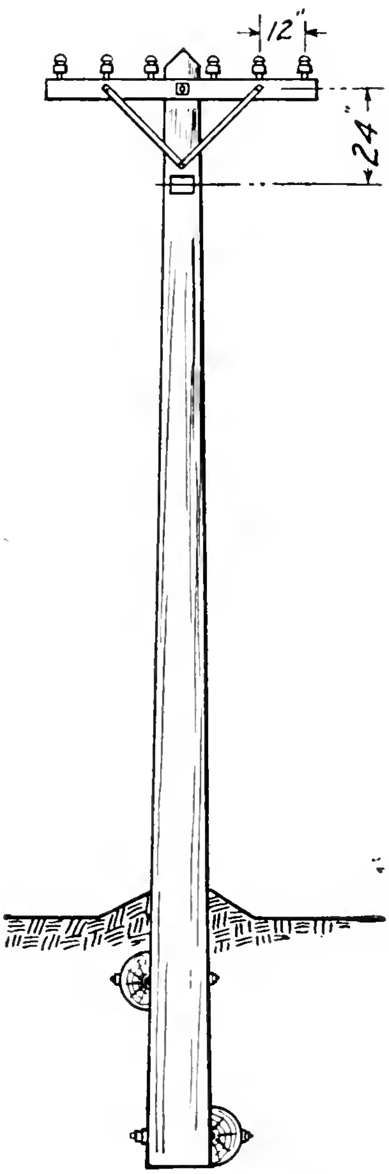


FIG. 351. *Pole with cross arm and ground brace—used on curves*

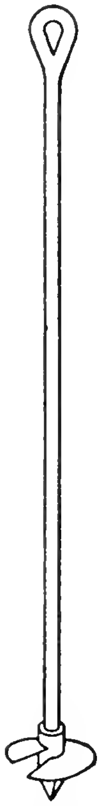
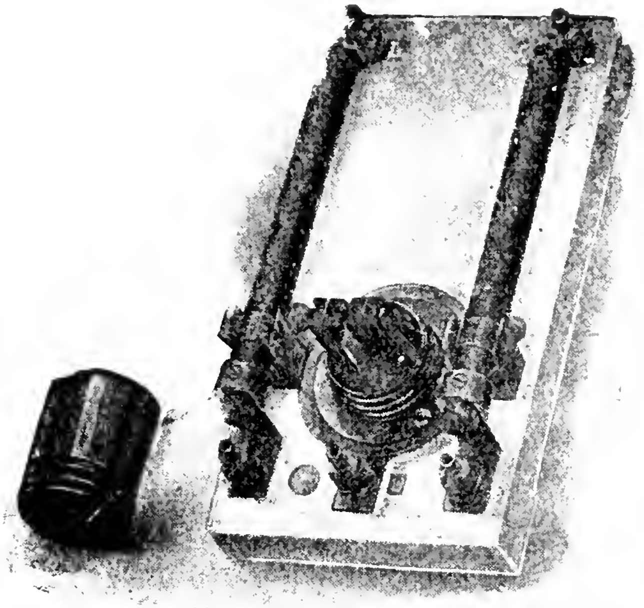


FIG. 352. *Metal anchor for screwing into earth and attaching guy wire (for log and plank anchors or "dead men" (see chapter on fencing)*

Where only two wires are to be carried, it is customary to attach brackets to the poles by means of wire spikes. Where more than two wires are to be carried, cross arms equipped with pins are used. The brackets as well as the pins are threaded to receive the glass insulators, which are necessary to insure a minimum of loss of current.

Protection. The connections between the pole line and the building, such as a dwelling house, may be made by means of bare wire, such as is used for the line proper, but while metallic circuits are used it is better to use insulated wire in a twisted pair. If bare wire is used, it is necessary to draw it tight to reduce the probability of the two wires swinging together, and the humming of tight wires attached to buildings is objectionable. If paired insulated wire is used, it may be left fairly slack between the nearest pole and the house. For attaching the wire to the house, porcelain or glass insulators attached by means of large wood screws are very satisfactory where the building is of wood. On brick or stone buildings expansion or toggle bolts set in drilled holes are used.



After Western Electric Co.

FIG. 353. *Protector used for lightning and where lighting and power lines cross telephone lines*

Where the wires pass through the walls of the house, porcelain tubes should be used, and directly inside a lightning arrestor should be installed. From the point where the wire from the pole is attached to the building to the point where it passes through the wall, it should be carried on porcelain or glass insulators. The principal reason for this is that heavy lightning discharges sometimes heat the wires to such an extent that they constitute a fire hazard if supported directly against the woodwork.

A satisfactory form of lightning arrestor is one having blocks of carbon held between flat springs, the carbon blocks being separated by a thin piece of mica, a part of which is cut away, thus leaving an air gap. One of the blocks is in electrical contact with a line wire and the other is connected with the earth. Currents which may be dangerous, either to the telephone instruments or to their users, will tend to discharge across the space between the carbon blocks.

A satisfactory ground connection for the lightning arrestor may be made by means of a 6-foot iron rod, having a wire soldered to it, driven into moist earth as a lightning rod is grounded. The connection from the lightning arrestor to the ground rod should be made by means of No. 14 B & S gauge braided rubber-covered copper wire, run as straight as possible from rod to arrestor, and protected against woodwork by porcelain knobs and tubes, as this wire is also subject to heating.

From the lightning arrestor to the telephone instrument, No. 18 gauge twisted-pair braided, rubber-covered house wire should be used.

The type of telephone instrument to be selected will depend largely on the kind of service which is decided upon. It would be well to consult with the representatives of reliable manufacturers of telephones, and, with the useful data which they can contribute, to make a selection of instruments which will fulfill the requirements.

SUMMARY

Briefly summarized, the important steps to be taken preparatory to building a privately owned telephone line are as follows:

1. Determine whether the line is to be isolated, or a part of an exchange system.

(*a*) If the former, is it to be metallic or a ground circuit?

(*b*) If the latter, is it to be a metallic or ground circuit, local or common battery, selective, semi-selective, or non-selective (code-ringing) type?

2. What size and kind of wire shall be used for the line?
3. Are more than two wires to be carried on any part of the pole line?
4. What lengths of poles will be required, and the number of each length?
5. The telephone instruments to be used.

Before undertaking to build a telephone line, it would be well to have in hand a complete treatise on the subject. Many useful data regarding specific questions can be obtained from the telephone trade publications. After the available facts have been collected, and definite action is taken on them, a day or two spent with a competent telephone engineer will be of great assistance to one in reaching correct conclusions as to procedure.

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PART V. MECHANICAL EQUIPMENT

CHAPTER XXIII

PRINCIPLES OF MACHINES

FUNDAMENTAL DEFINITIONS

Machine. A *machine* is a device for doing work when some source of power is applied by means of an inclined plane, a lever, a pulley, or a combination of the three. The wedge, screw, wheel and axle, and pulley are usually called *simple machines*, but the principles involved in them are covered in the *lever*, *inclined plane*, and *pulley*. All machines, no matter how complex, may be reduced to these three simple elements.

The word "machine" is applicable to any device with one or more moving parts, and *tool* to one that has no moving parts; but in common usage of the terms this distinction is not always observed. Devices with moving parts are frequently called tools. This is especially true when some simple device has been replaced by a machine. Many of the hand tools used in the trades have been replaced by mechanical devices which increase the ease and speed of an operation, but the word "tool" is still applied to the collection of devices that make up the individual working outfit of that trade. The only equipment for haymaking, at one time, was the scythe and hand-rake, which were properly called tools. While these tools have been replaced by the mowing machine, self-dump rake, and other mechanical appliances, all of which are machines, the term "haying tools" is still applied to them. The term "farm implement" is applicable to any equipment used in the performance of farm work.

Correctly speaking, a fork is a tool, a self-binder a machine, and both are implements.

Force. *Force* is the action exerted by a body tending to cause a change in the motion of another body. When a force causes a change in the state of motion of a body, *work* is said to be done. The ability to do work is *energy* and may be classified as *potential*, or energy of position, and *kinetic*, or energy of motion. A flowing stream has potential energy; if a dam is built, power will be developed. The water falling over the dam has kinetic energy owing to its motion, and the water stored up back of the dam has potential energy owing to its position. The sources of farm energy are feed, fuel, wind, and water. The unit of work is the *foot-pound*, or one pound acting through a distance of one foot (vertical lift). *Power* is the rate of doing work, the unit being the horse power. The value of a horse power is supposed to have been derived from the average rate of work done per minute by a horse in hoisting coal in the English mines. It is equivalent to the weight in pounds multiplied by the distance moved vertically in one minute in feet divided by 33,000. Horse power is indicated by "h. p."

Friction. In order that one may perform work with a machine, a certain degree of power must be applied to the machine which in turn performs the work. The power delivered to the work is always less than the power supplied to the machine. The power consumed in the operation of the machine is due to friction. *Friction* is the resistance which one surface offers to another sliding over it. This sliding takes place in a machine wherever there is motion. The *efficiency* of the machine is the ratio of the power applied to that delivered to the work. If 20 horse power is applied and only 15 horse power delivered, the efficiency is 75 per cent, one-fourth of the power being lost between its application to the machine and delivery to the work. The *coefficient of friction* is the ratio between the force holding the surfaces together and the force at the plane of contact between the two surfaces necessary to cause one to slip over the other. If it requires a force of 2 pounds to move a 25-pound weight over a surface, the coefficient of friction is .08. The coefficient of friction is always greater in starting a surface to slide than is required to keep it moving after it is once in motion.

MEANS OF REDUCING FRICTION

When a load is moved, the pounds actually hauled by a given tractive force can be increased in one of two ways: First, by *lubrication*, or the interposing of a hard, smooth film under the load. A sled moved over ice or well-packed snow is a simple application of this principle. Secondly, by the introduction of a *rolling surface* under the load, of which the wagon is a practical application. The application of these two principles for decreasing friction in the hauling of loads is made use of in machines to increase their efficiency by reducing the friction in the moving parts.

Lubrication. A lubricating substance is one that may be applied between sliding surfaces that will form a smooth film and decrease contact between the two. The film reduces the wear and heating occasioned by the motion. The substance suitable for lubricating material varies with the physical conditions of the moving surfaces. It must be a substance that will spread over and adhere to these surfaces. Great pressure requires a sticky or viscous substance, and heat, one that will not be burned or evaporated. The ice acts as a lubricant under the sled; the water, in the moving parts at the lower end of a pump rod, where the pressure is light; while the interior of a gas engine requires the best prepared lubricant on account of the close-fitting parts and great heat. Various prepared lubricants in either solid or fluid form, to meet the requirements of mechanical devices, are on the market, usually under the name of oil or grease. Finely ground graphite or mica in combination with grease is much used for a lubricant. Heavy lubricants are used

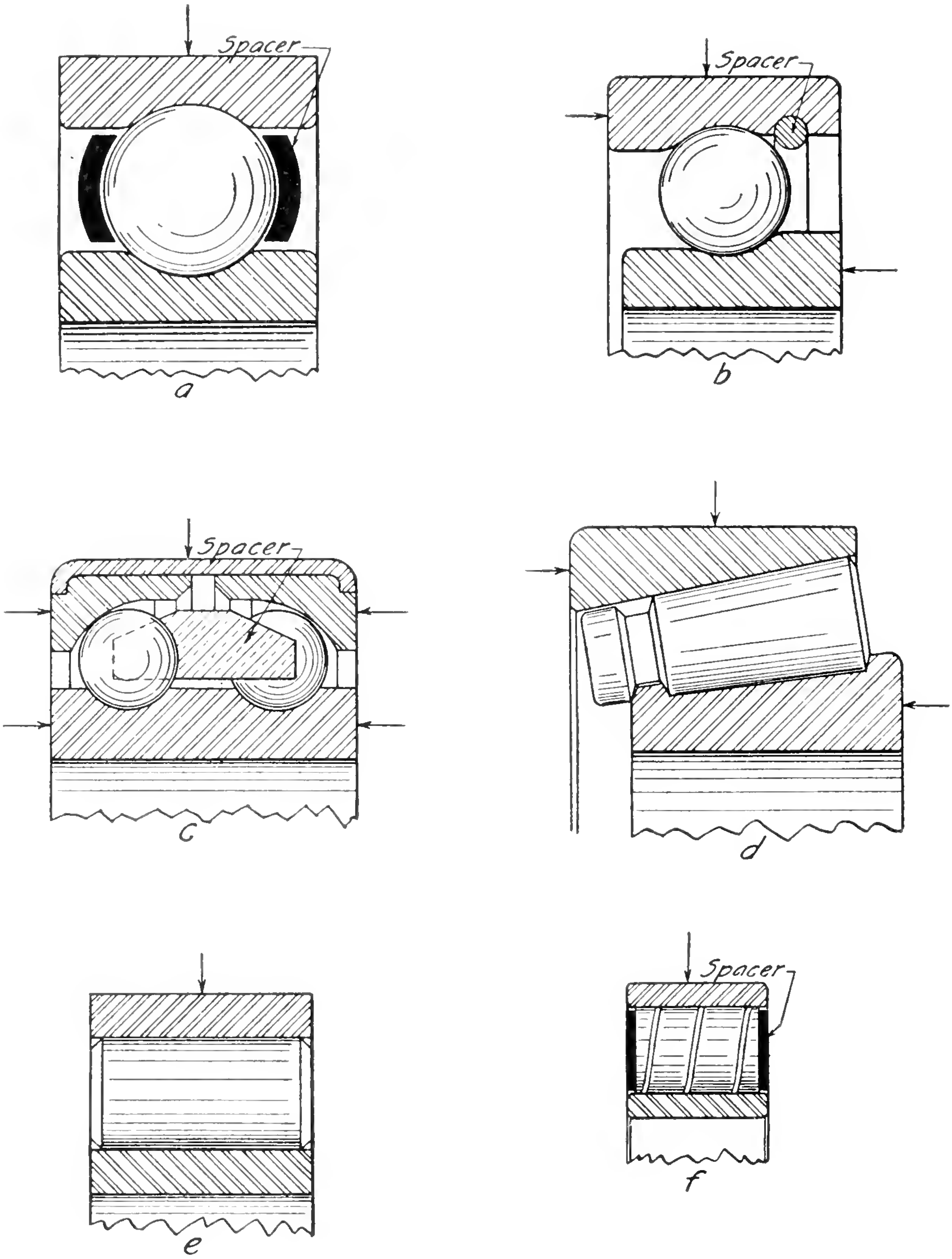


FIG. 354. *Types of ball and roller bearings*

a—Single-row annular ball bearings
b—Radax type ball bearing
c—Double-row annular ball bearing
d—Taper roller bearing (Timkin)
e—Solid roller bearing
f—Flexible roller bearing (Hyatt)

Arrows indicate direction in which each will take load and thrust.

where there is pressure or slow motion; light lubricants are used for high-speed machines, in which pressure is not great. The following terms are used in the description of lubricants:

Specific gravity: Weight of the lubricant as compared with pure water.

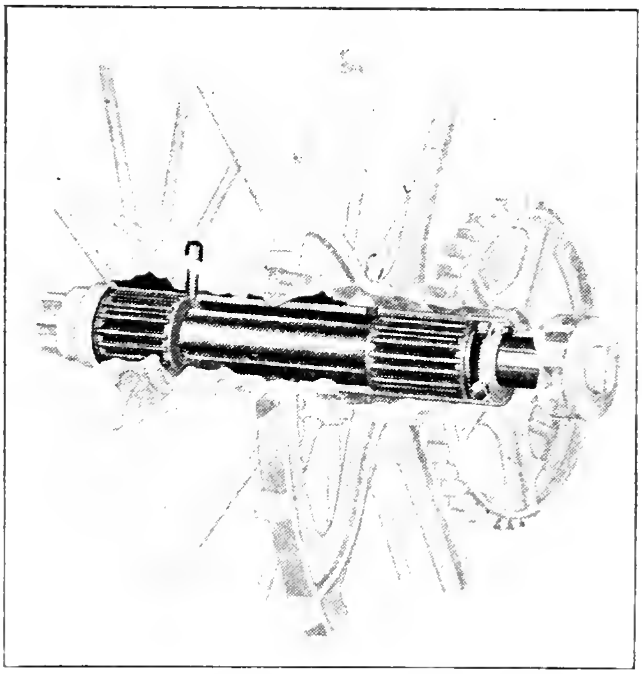
Viscosity: Number of seconds required for a given quantity to pass drop by drop through a small opening at a fixed temperature.

Flash point: Temperature at which the oil will begin to give off a gas which will burn.

Fire point: Temperature at which the oil will continue to support a flame. (The difference between the flash point and the fire point is usually not many degrees.)

Chill point, or cold point: Temperature at which the oil will cloud and cease to flow.

Rolling surface. A cylindrical-shaped body rolling over a surface has less friction than a plane sliding over another plane. Where the space will permit and expense justify, the insertion between the two surfaces of a series of very hard metal balls or rollers substitutes rolling for sliding friction. This is the principle applied when four wheels are placed under the load on the wagon. There are several types of this form of a non-friction device (Fig. 354). Some are made up of spheres; others, of cylindrical or taper rollers, known as *ball* and *roller bearings.* These bearings not only lessen the friction, but they assist in spreading and holding the lubricant.



After International Harvester Co.

FIG. 355. *A shaft supported by roller bearings*

TRANSMISSION OF POWER

Shafting. A *shaft* is a rotating medium through which power is transmitted and distributed. It is supported by and rotates in bearings held in the frame of the machine or by boxing held by supports or hangers. The part of the shaft which enters the bearings is frequently known as the *journal.* Jointed sections of shafting have been used to transmit power for a considerable distance, as in the tumbling rod of the horse-power grain dump. Shafting is usually made of cold rolled steel. The formula for finding the safe maximum horse power transmitted by a shaft of a given diameter is as follows:

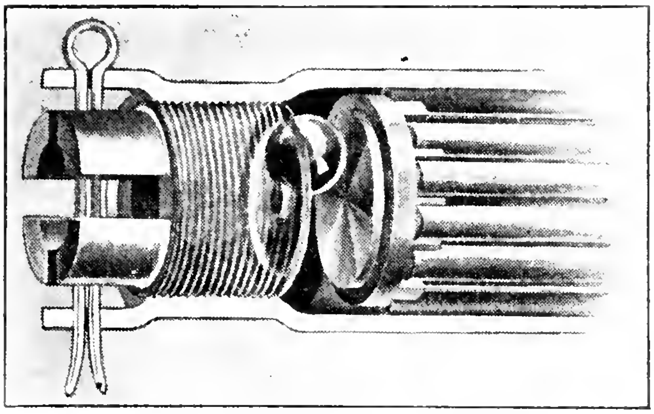


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FIG. 356. *An adjustable end-thrust ball bearing at the end of shaft supported by roller bearings*

$$\text{h. p.} = \frac{d^3 N}{50}$$

where d = the diameter of the shaft in inches and N = the number of revolutions per minuter (r. p. m).

The power is applied to the shaft by one of several well-known methods.

Pulley. The pulley for the transmission of power to the shaft through a belt is one of the most common forms. Pulleys are made of wood, cast iron, and steel. The wood pulley is cheap and can be had in two parts which make it convenient to attach, but it is not very lasting and will not transmit much power. Metal pulleys may be made in two parts, are long-lived, and the surface may be covered with leather to increase the friction. The one supplying the power is known as the *drive pulley,* the other as the *driven pulley.* To find the velocity of a pulley in feet per minute, multiply the circumference in feet by the number of revolutions per minute. To find the speed of a driven pulley, multiply the diameter of the drive pulley in inches by the number of revolutions per minute and divide the product by the diameter of the driven pulley in inches. The quotient will be the number of revolutions of the driven pulley per minute (commonly designated as r. p. m.).

Belting. A common form of transmission of power is by means of a belt running from the drive pulley to a pulley on the device to be driven. The transmission of power between the pulleys and belt is by friction. When the load becomes too heavy, one or both pulleys slip within the belt and the driven machine stalls. To increase the power of the belt, it is necessary to increase the friction by widening the belt and the face of the pulley or by increasing the diameter of both drive and driven pulleys. Where only a small amount of power is transmitted, a shaft may be driven at an angle to the drive shaft by means of an *idler*, "a pulley without a load," placed in line with both pulleys, which will turn the belt in the required direction. With a light load a belt may be crossed between the pulleys which turns the driven pulley in the opposite direction to that of the drive pulley. Heavy loads require that the belt run straight from pulley to pulley and in the direction of the drive pulley. For a belt to operate properly, it should run as slack as is possible without slipping, be tight on the under side, the pulley centers not too close together, and the pulleys crowned (slightly curved on the surface) and exactly in line. "Crowned" pulley is distinguished from "straight-faced." Where a straight-faced pulley is required (as, for example, opposite a pair of "tight and loose") a "crowned" pulley will not work.

a) Leather belting: Leather is the standard belting material where it is dry. It should run with the smooth side next the pulley, and, to prevent cracking, should be occasionally treated with neats-foot oil or a belt dressing. Leather belts for pulleys larger than 10 inches in diameter may be had in two-ply or more which is a multiple thickness of leather.

b) Rubber belting: Rubber belts are used where there is escaping steam or dripping water and are made of canvas thoroughly coated with rubber and are two- to eight-ply in thickness.

c) Canvas belting: Canvas belts are made of from two- to ten-ply canvas sewed together, thoroughly saturated with oil and then painted. They are strong and the cheapest

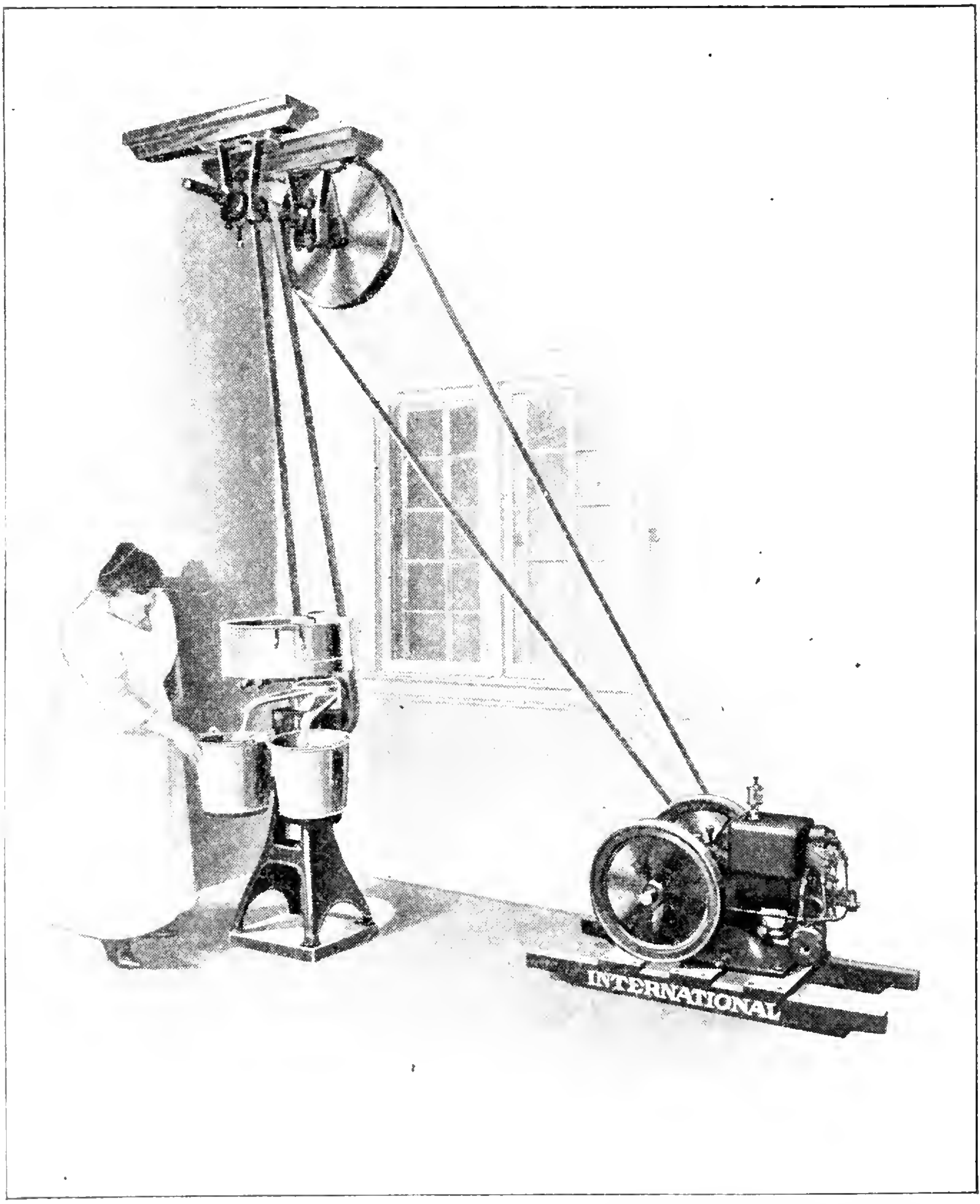

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FIG. 357. *Transmission of power by pulley and belt*

form of belt. Their lengths change with moisture conditions, and they can be used only where it is not necessary to maintain a fixed distance between pulleys. They are suitable for the belting of a farm motor to a portable machine or where a belt tightener can be used. Belts should be of sufficient width and pulleys large enough to transmit the power without the application of resin or other substances to the face of the pulley. These materials injure leather belts and destroy rubber. The power transmitted by a single-ply leather belt can be calculated as follows:

$$\text{h.p.} = \frac{VW}{1000}$$

where V = velocity of belt in feet per minute and W = width of belt in inches.

Where it is not practicable to use endless belts, a variety of metallic fasteners may be found in the market for connecting the ends, some of which are very desirable for high-speed belts or where idlers are used. The common method of fastening belts used on the farm is by lacing the ends together with a belt lace which is a narrow strip of rawhide cut from lace or whang leather. Before the lacing is done the ends of the belt must be cut square with the edge, holes punched, and the leather inserted as shown in Figure 358, page 470. There should be no knots or crossing of the lace on the side next the pulley.

d) Chain-and-sprocket or link belts: Sprocket wheels attached to the shaft in the same way as a pulley, and connected by endless chains made up of rectangular-shaped links, are used a great deal on agricultural implements. The links are made of malleable iron or steel, and one can readily be taken out or put in. They are a positive drive and do not permit slipping. In the case of an overload the power must stall or the machine will break. On account of the links not fitting the sprockets snugly there is a given amount of lost motion. These belts are noisy and cannot be operated at high speeds.

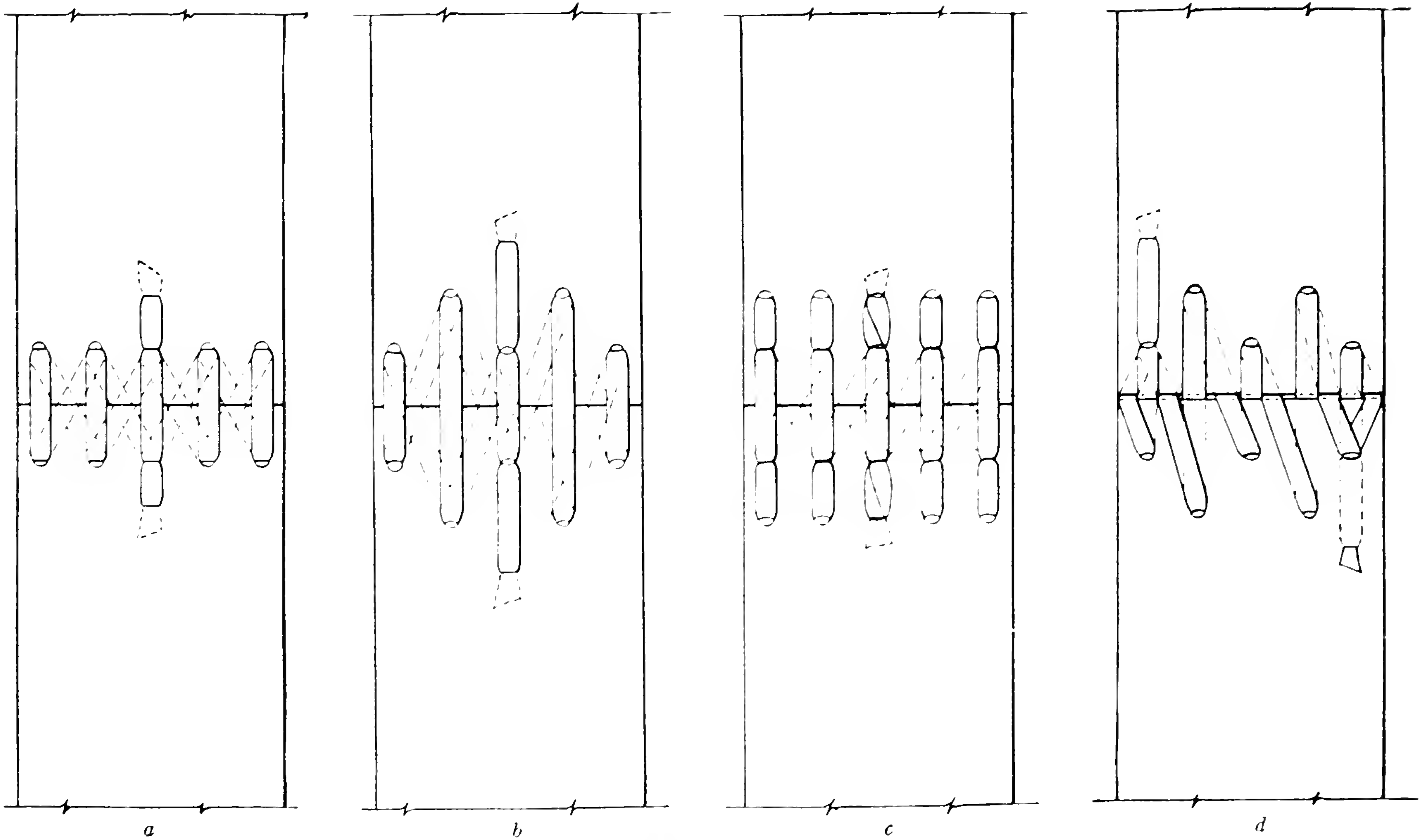

FIG. 358. *Methods of lacing belts*

3-inch leather belt holes $\frac{5}{8}$ inch apart and $\frac{5}{8}$ inch from end of belt

a—Ordinary load, slow speed
b—Ordinary load, slow speed
c—Heavy load, high speed
d—Hinged lace for high speed and small pulley

c) Rope transmission: Rope (Fig. 360) has been used to a limited extent for transmitting power long distances and where the shafting is not parallel. The rope can be changed in any direction by means of an idler. The sheaves (pulleys) over which the rope runs should be grooved to grip the rope. Some method of tightening must be employed, as the length of the rope is variable. Where the drive is exposed to the weather a wire cable is used in place of a rope, but in this case the sheaves should not grip the cable.

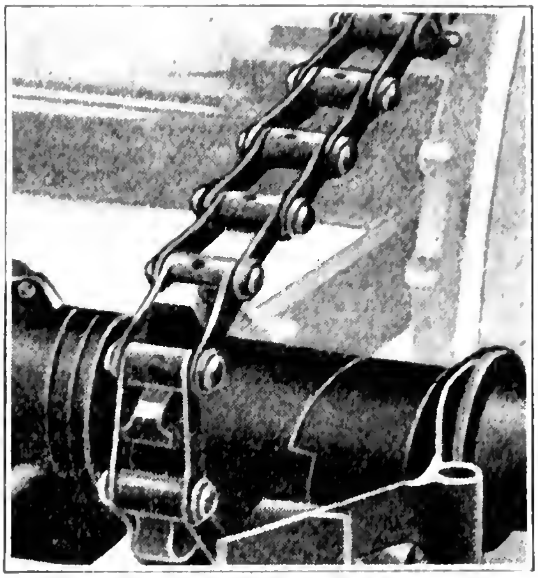

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FIG. 359. *Link belt and sprocket wheel*

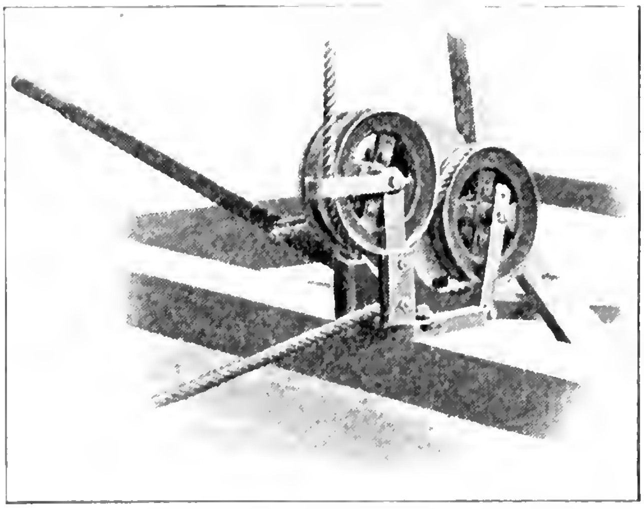

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FIG. 360. *A rope belt*

Cog gearing. Cog gearing is used for a positive transmission of power with a minimum of slack motion. The teeth are carefully designed and cut for rolling contact between tooth surfaces. When the two shafts are parallel, the teeth are placed on the rim and the gears are called *spur gears* (Fig. 361). When the shafts are at an angle and in the same plane, they are *bevel gears* (Fig. 362). *Spiral* and *worm gears*

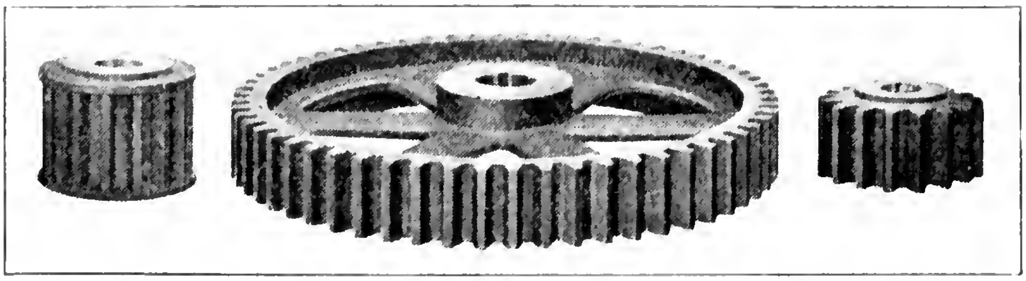

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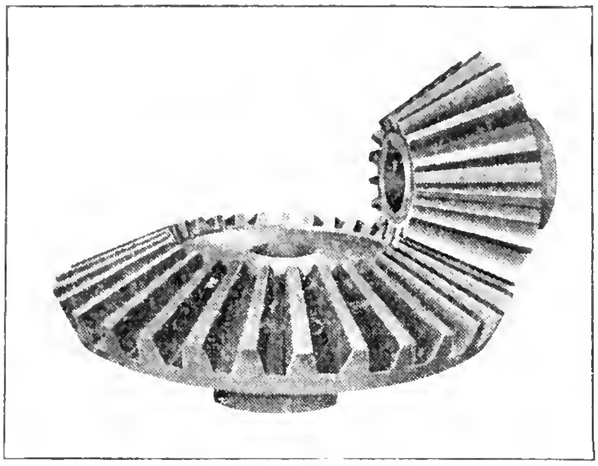
FIG. 361. *Spur gearing*

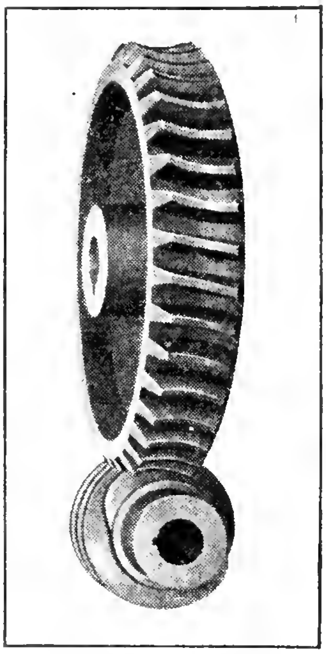


After Link Belt Co.
FIG. 362. *Bevel gearing*

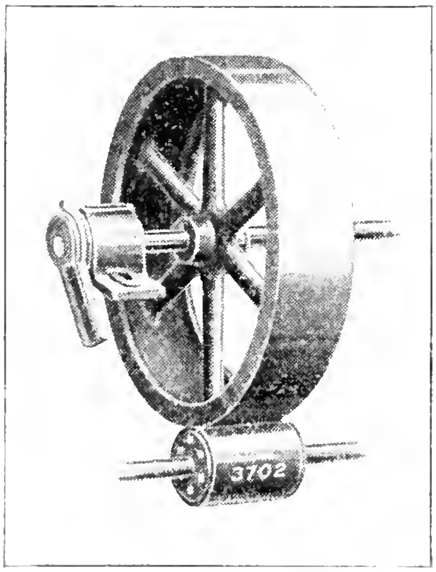
(Fig. 363) are used for shafts not in the same plane and usually at an angle. The smaller of the wheels in a cog gear is known as a *pinion*. Cog gears are noisy, expensive to repair when a tooth breaks, and dangerous if not protected by housings.

Friction gearing. Friction gearing (Fig. 364) is a metal pulley the surface of which is in contact with a paper- or rawhide-covered pulley. Such gears are used only where it is desirable to have slippage or to prevent undue strain or breaks, and will transmit only a limited amount of power.

Quadrant or triangle gearing. Quadrant or triangle gearing is used to transmit power in which the motion is reciprocating. The power of a windmill or gas engine which has been transferred to an up-and-down motion may be transmitted to a pump 75 to 100 feet distant, the transfer wires being overhead out of the way.



After Link Belt Co.
FIG. 363. *Worm gearing*



After Link Belt Co.
FIG. 364. *Friction gearing*

Circular and reciprocating motion. *a*) Connecting-rod and crank shaft: Power may be delivered as generated in a back-and-forth or reciprocating motion and at once transferred to circular motion, as by the connecting rod and crank shaft of a steam or gas engine.

b) Pitman rod: Power may be delivered in circular motion and transferred to reciprocating by a pitman rod, as in the windmill and pump or mowing machine, where the sickle runs back and forth, although the power is generated from the circular motion of the main wheels.

Ratchet drive. The ratchet drive (Fig. 365) gives an intermittent motion. Teeth are cut on either the interior or the exterior rim of a wheel, and pawls engage these teeth and cause motion when turned in one direction, but disengage and prevent motion when turned in the opposite direction.

Cams. A cam (Fig. 366) is a timing device used for transmitting intermittent motion. Cams are set on a revolving shaft, and the rims, to a greater or less extent, are eccentric. As the shaft revolves, the cam presses on the "follower," causing motion. The follower is pressed against the cam by gravity or the action of a spring.

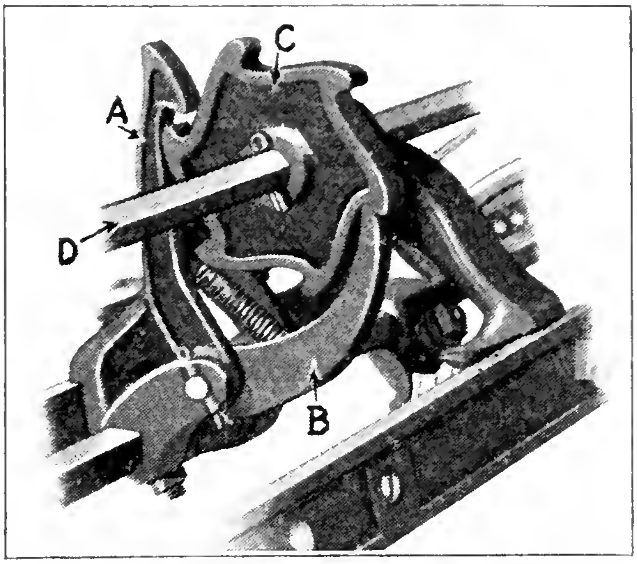


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FIG. 365. *Ratchet driving device*

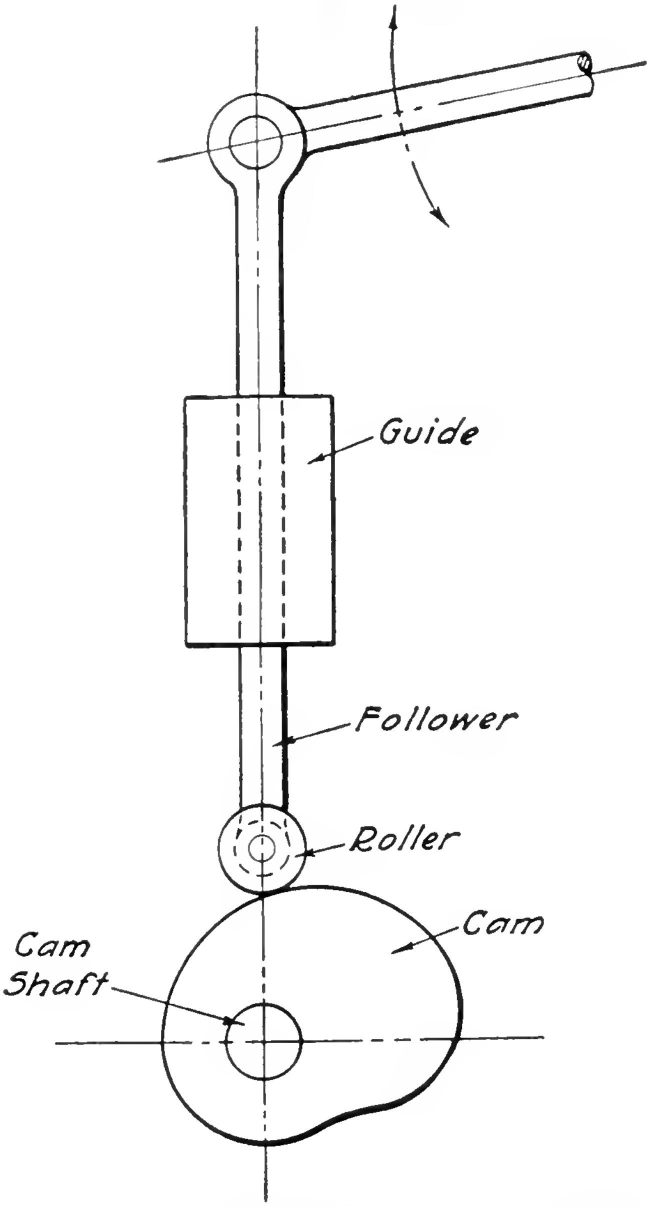
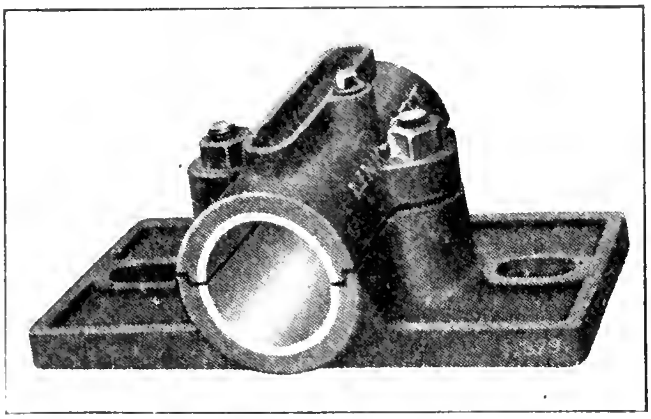


FIG. 366. *A cam with follower and guide*

Bearings. Bearings are the supports of the rotating parts of a machine. Bearings which are separated from a machine are called *boxes.* A solid box bearing is in one piece, and a split bearing is in two parts. (Fig. 367). A self-aligning bearing has a hanger or support which will permit of the aligning of its axis. A bearing has a suitable lining held in a cast yoke that can readily be replaced when worn. The lining is designed to permit the necessary lubrication and is made of material that has a low coefficient of friction and is softer than the journal.



After Link Belt Co.

FIG. 367. *A standard babbit bearing*

Types of bearings. Bearings are made of hard wood soaked in oil, babbit, brass, and bronze. Bearings should be properly adjusted. If too tight, they will heat; if too loose, they will knock and heat.

Lubricating devices. Complete provision should be made for lubricating all bearings. Various types of oil and grease cups are supplied to meet the requirements of lubrication. In farm implements special provision is made to prevent the entrance of grit and dust into wheel bearings by means of a cup placed on the outer end of the box, and a dust collar on the inner end. A heavy lubricant is applied by the method of screwing off the cap and placing it at the outer end of the box, from which it works to the inside.

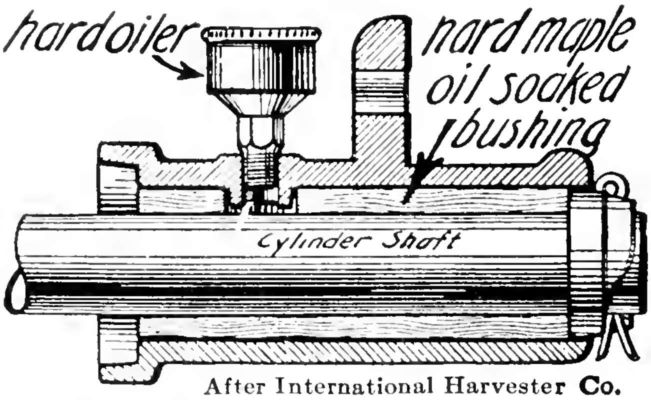


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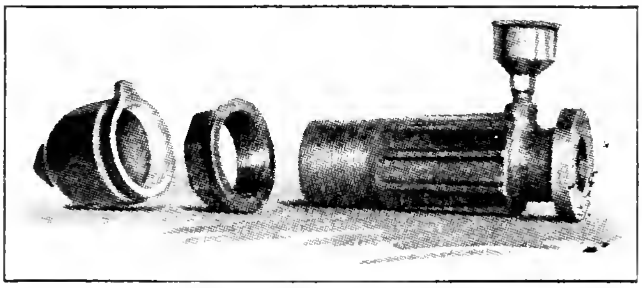
FIG. 368. *A wood bearing with oil cup*

CHOICE AND CARE OF MACHINES

Durability. The durability of a farm implement will depend on the material of which it is made, the attention given it while it is in operation, and the care taken of it when it is not in use. In the selection of a farm implement due consideration should be given to the local conditions where it is to be used, to the nature of the crop grown, and often to soil and moisture conditions. A study of the advantages and disadvantages is desirable, especially if the machines can be seen in operation under different conditions. Dealers are usually interested in supplying a standard make of implement that experience has proved to be suitable for local requirements. A low first cost may not mean a cheap machine, and one that is not standard will be expensive to keep in repair. Extreme sizes are not advisable, for if the machines are too small the work is rendered slow, and if too large they are subject to great strain and more power is required to operate them. There is usually an advantage in having all equipment along the line of medium requirements.



After International Harvester Co.

FIG. 369. *A removoble hub bushing, lock nut, and hub cap for a cultivator wheel which may be replaced when worn*

Bearings and pinions are generally the parts subject to greatest wear and should be replaced by new ones without delay. The oil-saturated hardwood bearings have been found satisfactory in many instances. The implement which will efficiently perform the work and has the least number of moving parts will be the most desirable. Nothing is gained by an increase in the number of moving parts unless better work or more work with the same power can be accomplished. Tillage implements working in the fresh soil are subjected to dirt and grit, and the boxing should be specially protected to prevent their entrance into the bearings, and provision should be made for replacing the boxing when worn without buying a new wheel. To decrease the draft of such implements as have wheels, the tires should be broad and concave and the wheels high. Some bearings, such as those of the pitman of a mowing machine or the disks of a harrow, are subject to thrust or side pushing and they should be bearings adjustable to wear.

TABLE, COMPILED FROM A LARGE NUMBER OF EXPERIMENTS SHOWING THE NUMBER OF FEET AND SECONDS REQUIRED TO TURN FARM IMPLEMENTS

Implement	Distance in Feet Required to Turn	Average Time in Seconds Required to Turn
Sulky plow, 4 horses abreast	17	42
Sulky plow, 3 horses abreast	17	35
Gang plow, 4 horses abreast	18	41
Walking plow, 2 horses abreast	17	47
Gang plow, 5 horses, 3 abreast, 2 in lead	28	75
Harrow, 5 sections, 4 horses abreast	22	28
Harrow, 2 sections, 2 horses abreast	15	13
Disk harrow, 4 horses abreast	15	21
Grain drill, 4 horses abreast	14	37
Grain drill, 2 horses abreast	14	27
Corn planter, 2 horses abreast	18	69
Sprayer, 1 horse	16	20
Single-row cultivator	15	18
Two-row cultivator, 3 horses abreast	16	20
Potato digger, 4 horses abreast	20	47
Reaper, 5-foot cut, self-rake, 2 horses breast	18	20
Corn binder, 3 horses abreast	18	46
Corn binder, 4 horses tandem	28	25
Grain binder, 4 horses abreast	19	45
Tractor, see data supplied by manufacturers.		

Care of machines. When a new machine is started, extra attention should be given to the bearings for two or three days. If they heat, they are too tight, dirty, or not properly lubricated. Care should be taken that in no case a bearing or gear runs dry. Knives and cutters intended to have a keen edge should be kept sharp and be replaced when worn or broken. The manufacturer's instructions for operating and oiling an implement should be carefully studied and rigorously followed. The wood and iron parts of an implement should be kept thoroughly clean at all times. When the implements are not in use, the polished surfaces should be rubbed until dry and coated with heavy grease or oil to prevent rusting. They should then be placed under cover. If they are not dry when the grease is applied, they will rust under the coating. When a machine is placed in the shed at the end of the season, a tag should be tied to it showing the repairs needed. In the slack period during the winter the repairs should be ordered and the implement put in shape before the busy season begins.

CHAPTER XXIV

MOTIVE POWER

The motive power for farm work was originally man himself; then animals of various breeds were trained to supply the simpler forms of energy. The horse, being the best adapted by nature for tractive purposes, has superseded all other animal power and become the accepted standard of farm power.

The wide application of certain forces of nature in combination with mechanical applicances for the production of power in the industries has led to the development of mechanical equipment that under given conditions may be used to replace difficult and laborious operations on the farm.

THE HORSE

Pulling power of the horse. A horse pulls by means of his weight, his muscles supporting the body and moving it through space. It is considered that he can exert a pull equal to one-tenth of his weight when moving at a rate of 2½ miles per hour throughout the working day. The physical condition of the horse, his age, the weather, and the footing, all tend to decrease or increase his actual pull. For a short period he can exert one-half of his weight and in standing may be able to exert three-fourths of it on a load. However, such exertion can last for only a short period. The force exerted by a horse does not necessarily mean the load he can pull, as the load is dependent upon a number of conditions as discussed in the chapter on roads, but it indicates the force that he can apply to the load. If a strong spring balance were placed between the horse and the load, a 1,000-pound horse, if exerting one-tenth of his weight, would register a pull of 100 pounds on the balance. While there can be no definite amount given for the force which an individual horse should exert, the average pulling power is estimated at one-tenth of the weight of the animal.

Since the horse is attached to the load by means of a collar placed on his shoulders, his pulling has a tendency to raise his shoulders from the ground and pull him over backward on a pivot, which is the point on the ground under his hind feet. The heavier the horse, the more force is required pulling backward to resist his pull. This condition gives rise to the statement that a horse can pull a heavier load with a man on his back than he can otherwise, since the weight of the man tends to hold him to the ground. The additional pull is the same as the extra exertion by the horse, and it tends to wear him out physically and lessen the period of time through which he can exert the pull.

Balancing team power. In connecting two or more horses to a load, either to a vehicle to be hauled on the road or to a machine for performing work, the horses should be of equal weight and strength if the most efficient team service is to be performed. When it is necessary to work horses together that are of unequal weight or strength, the inequality in the animals may be overcome by mechanical appliances. The mechanical appliance by which a team is attached to a load should be of such a nature that it will not place one horse at a disadvantage in relation to the other. The means of attachment is the *evener* or *doubletree*, the individual horses being connected with the evener by the *singletree* or *whiffletree*. (See Fig. 370.) If the draft pinhole or the singletree pinholes are not bored in proper relation to one another in the evener, one horse may be required to do more than his share of the work. The object to be attained when two or more horses are working on

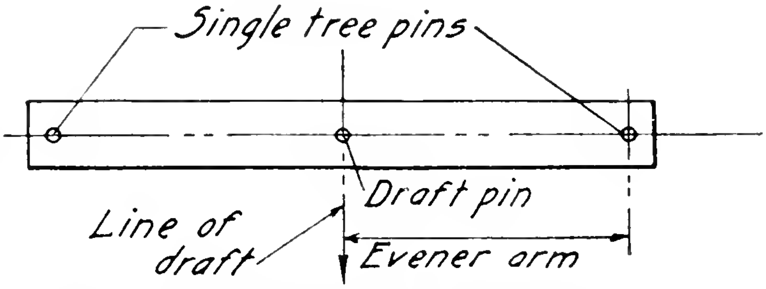


FIG. 370. *Showing the position of draft pin, singletree pins, evener arm, and line of draft*

the same load is to have each horse working at a rate which is commensurate with his strength and ability and not require him to pull more than his proportionate share of the load, in order to keep up with the heavier or more capable animals, for the efficiency of the team is dependent upon their united and not their individual efforts. If one gives out, the team power is disorganized. The pinholes in the evener should be so adjusted that when all of the horses are pulling their proportionate share the evener will remain exactly in line if the various parts are free to move back and forth according to the pull of the animals (Fig. 371).

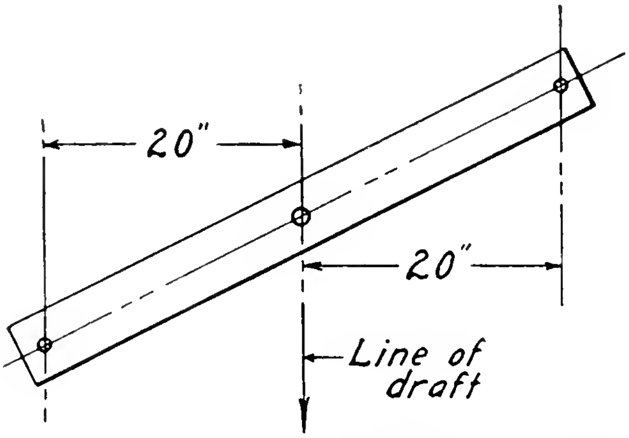


FIG. 371. *When the pinholes are in a straight line, the length of the evener arm remains the same irrespective of the inclination of the evener with the line of draft.*

When one horse is pulling more than another, adjustment can be made if the distance from the singletree pin to the draft pin is made shorter for the heavier horse than for the lighter. The proper relation can be expressed as follows: The pull of one horse multiplied by the length of his evener arm is equal to the pull of the other horse multiplied by the length of his evener arm. For example, if a 1,500-pound horse is worked on an evener with a 1,000-pound horse and the condition of the two animals is the same, one exerts a pull of 150 pounds as easily as the other a pull of 100 pounds. If the singletree pin for the heavier horse is 21 inches from the

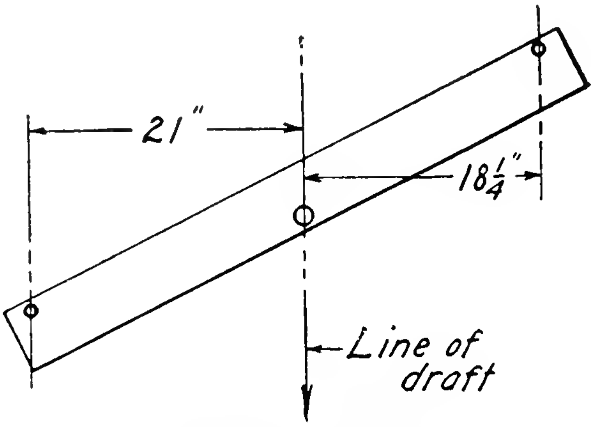


FIG. 372. *When the pinholes are not in a straight line and the evener is inclined to the line of draft, the evener arm which is farthest in advance will be longer.*

draft pin, the proper distance for the singletree pin for the lighter horse is determined as follows:

$$21 \times 150 = 100 \times x$$

$$x = \frac{150 \times 21}{100} = 31.5$$

Therefore the pin of the singletree of the lighter horse should be 31.5 inches from the draft pin. Then each animal will pull his proper share of the load. (See Fig. 372.)

Evener construction. In practice it is frequently necessary to keep the animals an equal distance from the tongue. This can be accomplished by means of shifting the evener at the draft pin, making all or a part of the adjustment there instead of making all of it at one end. In this way the proportion between the length of the two evener arms can be maintained. In the shifting of the draft pin a movement of 1 inch is approximately equivalent to moving the singletree pin 2 inches, since the singletree moves the pulling point of only one horse, while the draft pin moves both.

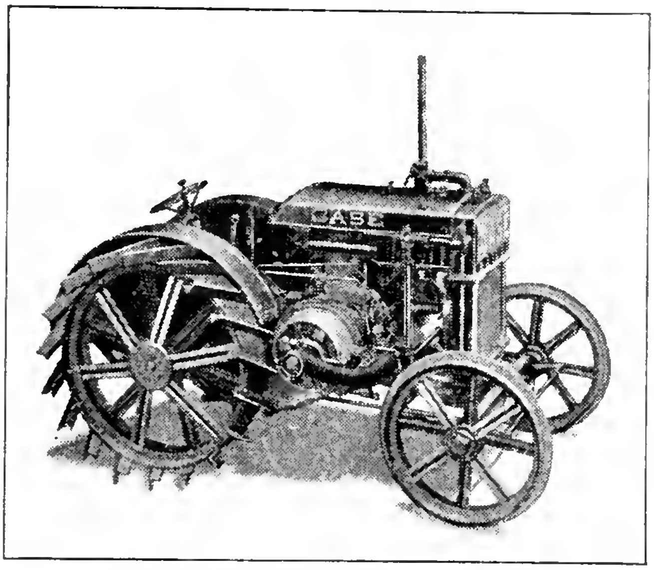
On a three-horse evener it is customary to hitch a team to a two-horse evener and attach that to the three-horse evener, having one horse attached to the long end with a singletree. The team can be balanced against the single horse if their combined weight is considered as that of one horse and the proper length of the evener arms is then computed as described for a two-horse evener. When the three animals are of equal weight, the evener arm for the single horse will be twice as long as the evener arm for the team. Four- or five-horse eveners can be adjusted on the same principle.

Position of clevise pinholes. Teams are not always matched in respect to gait or energy, one animal frequently having a tendency to travel ahead of the other. This causes the evener to take an inclined position with reference to the line of draft or tongue. Both animals will be pulling a proper proportion of the load so long as the evener arms remain at right angles to the tongue and the pinholes are all in a straight line. If the holes for the singletree pins are set some distance back of the draft pin, the rear horse will be pulling more than his share of the load, since the length of the two evener arms will not be balanced when the evener is inclined to the line of draft. The length of the evener arm is the distance, at right angles to the line of draft, from the draft pinhole to the singletree pin. This inequality increases as the draft pinhole increases in distance in front or back of a line connecting the singletree pinholes. Consequently, when the holes in the evener are constructed in this manner, the animal that hangs back must do more than his share of the work. This may be demonstrated in a laboratory by a board cut to represent an evener and balanced at the center on a nail, weights being used to represent the pull of the horses. The fact that one horse in the team travels ahead of the other is not an indication that he is doing more than his share of the work. The lead horse may have learned that by keeping in the lead he is doing less work than if he travels abreast of his mate.

An evener should be selected which has holes as nearly in line as it is practical to place them. By the use of iron plates and rivets to reinforce the wood, it is possible to arrange the holes so near in line that the load will be uniform on each horse, even though one is considerably ahead of the other. The efficiency of the team may be increased considerably if the evener is given proper attention and is so adjusted that each horse is working in accordance with his physical ability. Eveners should be as light as is consistent with strength. Tests made with commercial eveners indicate that wood eveners, properly made, are stronger than metal eveners of the same weight.

MECHANICAL MOTIVE POWER

Steam engines. The development of a portable steam engine, followed by the traction engine, made power available for sawing, grinding, threshing, and other stationary work that had been rendered slow and inefficient by the number of horses required to supply the necessary power. The expense and labor of operating a steam engine prevented its adoption as a farm power except on large farms having sufficient work to require an engine throughout a season for threshing, sawing, or other heavy work. The number of horses needed on a large grain farm to furnish the traction power for seeding, harvesting, and threshing was not sufficient to do the plowing in the limited season in which it had to be done. To avoid maintaining a number of horses for the plowing season only, the farm operators experimented with their steam tractors which, with a skilled crew, were available in the plowing season. The result was that the plowing could be done by the horses required for the other operations of grain farming supplemented by the steam tractor, and the practicability of plowing large unobstructed fields with steam threshing engines was clearly proved.



After J. I. Case Threshing Machine Co.
FIG. 373. *A wheel gas tractor*

Gas tractor. The development of the gas engine and its application to the small tractor (Fig. 373) operated by one man have placed a machine suitable for both tractor and stationary work within the possibilities of the ordinary farm. The desirability of adding a tractor to the farm equipment is open to much discussion. It is dependent on the mechanical ability of the landowner, the nature of the soil, the work that can be performed by the tractor, and the number of horses which are required to carry on the farm work in addition to the tractor. Men with mechanical ability prefer working with a machine rather than with a horse, and they substitute mechanical methods wherever practicable. Such an operator can get efficient service out of a tractor and perform much work with it that cannot be accomplished by one lacking such ability.

A hard dry soil is more successfully worked by a tractor than one that is wet. There is a tendency in some soils to pack and bake if pressed when wet, and this limits the weight which can be run over them by a machine used in cultivation.

Some of the operations which have been performed on a farm by a gas engine used as tractive power are as follows:

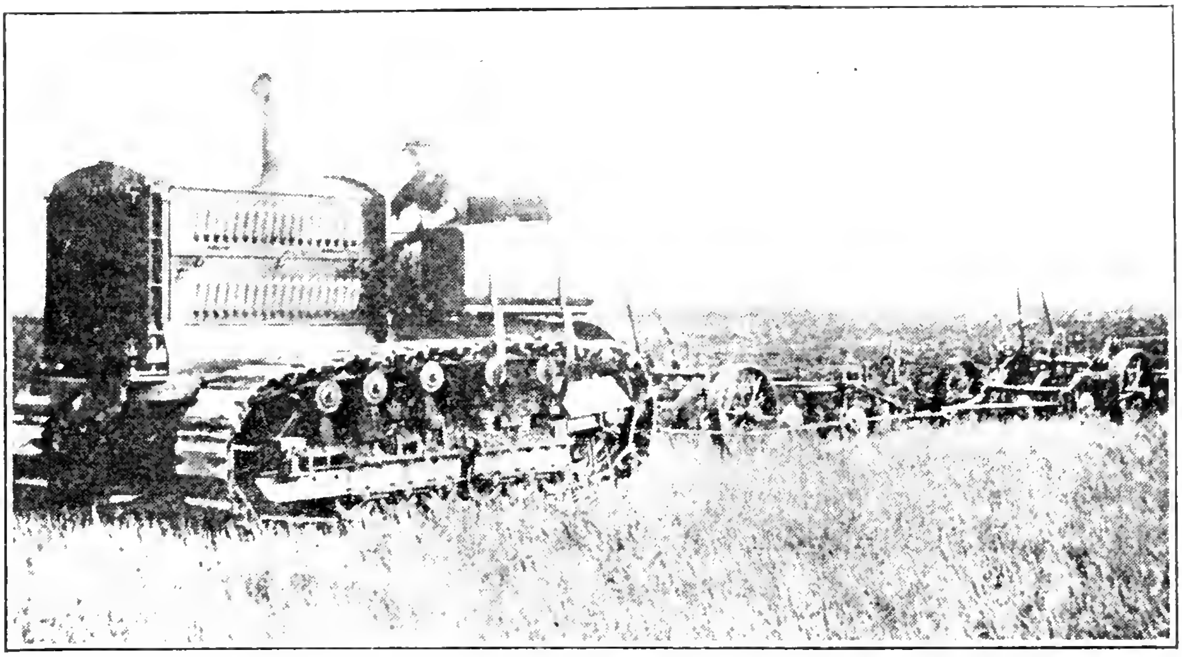
Building of levees
Building moving
Corn husking and binding
Clearing land
Disking
Fence stretching
Grain binding
Grain seeding
Harrowing
Hay loading
Hay unloading
Listing
Manure spreading
Plowing
Rolling
Road grading

Stationary or belt work as follows:

Clover hulling
Cider making
Corn shelling
Corn shredding
Concrete mixing
Ensilage cutting
Feed grinding
Grain threshing
Grain elevating
Hay baling
Lumber sawing
Water pumping
Wood sawing

These activities show the adaptability of the tractor to farm work. Many of these uses are exceptional, and only a few of them are ever called for on any one farm. The gas tractor is more suitable for belt work on the farm than the steam engine.

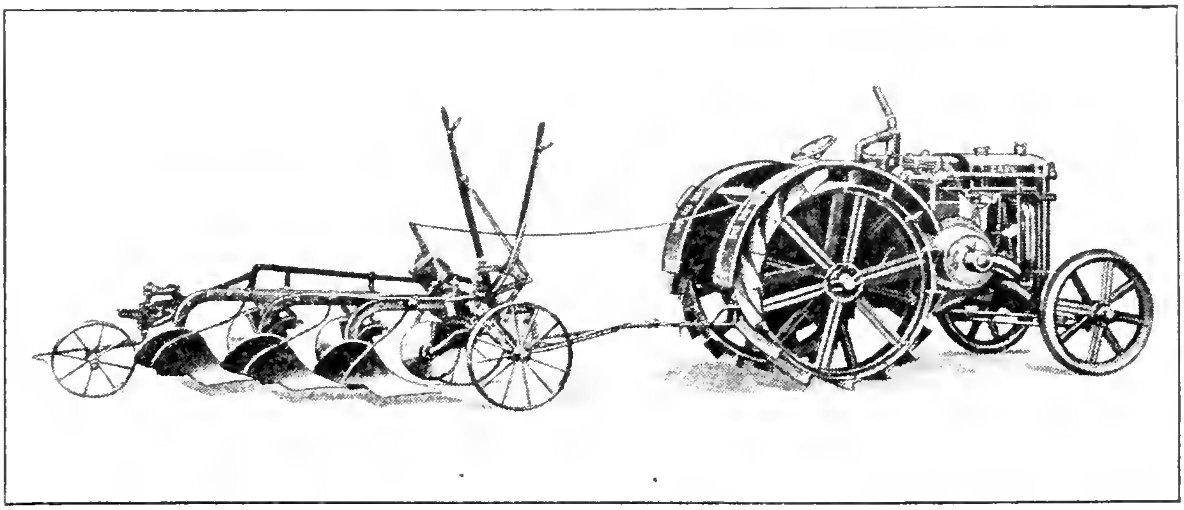
Plowing is the farm tractive work that lends itself most readily to the tractor. By use of a "caterpillar" traction (Fig. 374) or extension rims on the drive wheels, tillage, seeding, and harvesting machines have been operated on peat and soft soils which would not support a horse. Plows have been satisfactorily pulled through gumbo soils, newly cleared land full of small roots, and hard dry soils where it was impossible to use horse-drawn plows (Fig. 375).



After Holt Manufacturing Co

FIG. 374. *A "caterpillar" gas tractor*

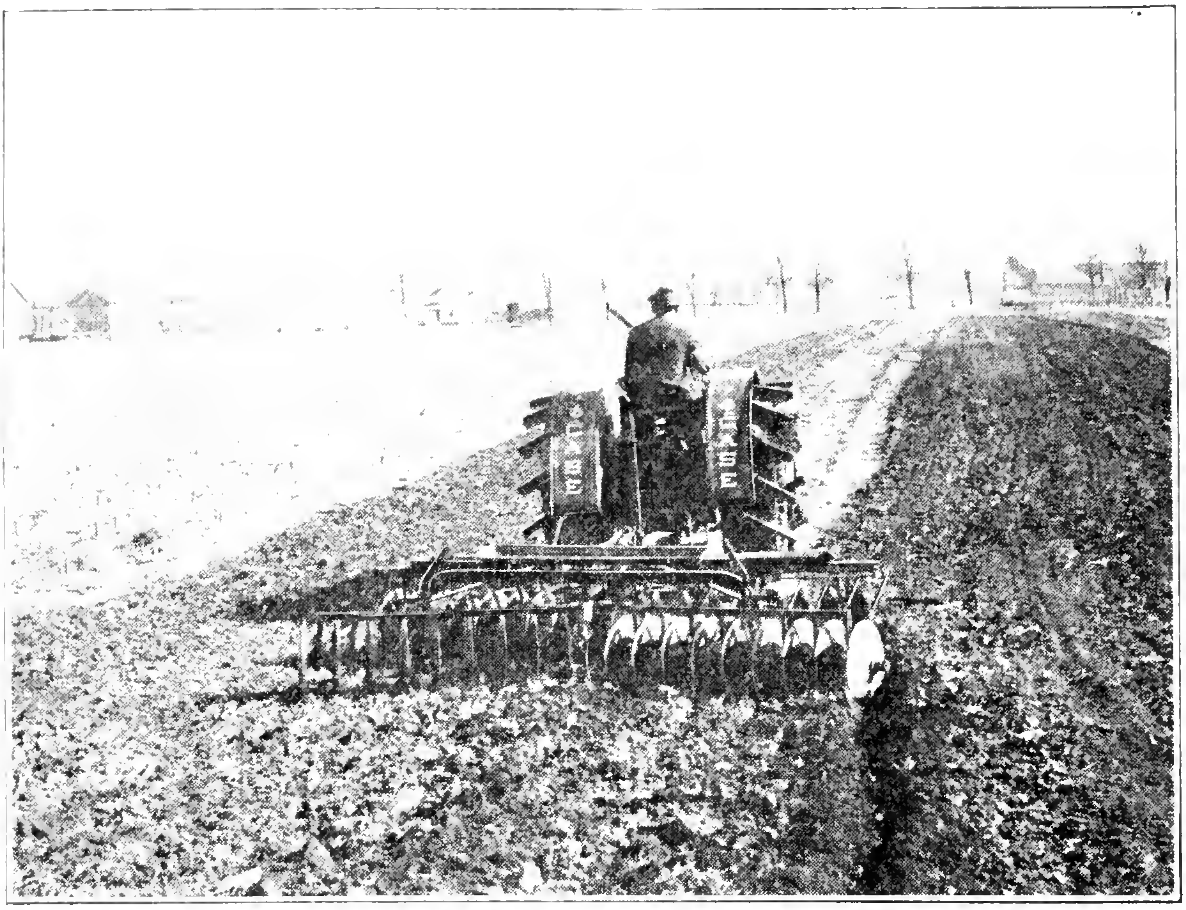
The number of plows drawn is dependent upon the size of the tractor. A tractor of sufficient power to perform the heaviest work required of it is purchased, and the number of plows is then adjusted to its strength. On the ordinary



After J. I. Case Threshing Machine Co.

FIG. 375. *A gas tractor drawing three plows*

farm a tractor capable of pulling two or three plows, with the preference for the three-plow size (Fig. 375), has been found to be the size best suited to other work. The average number of acres plowed per day per plow decreases as the number of plows increases. This is accounted for by the fact that the cleaning of a choked plow requires all the plows to stop, and the number of cleanings increases with the number of plows. Fields suitable for tractor plowing should be long, regular, and free from obstructions through which the plow cannot be drawn.



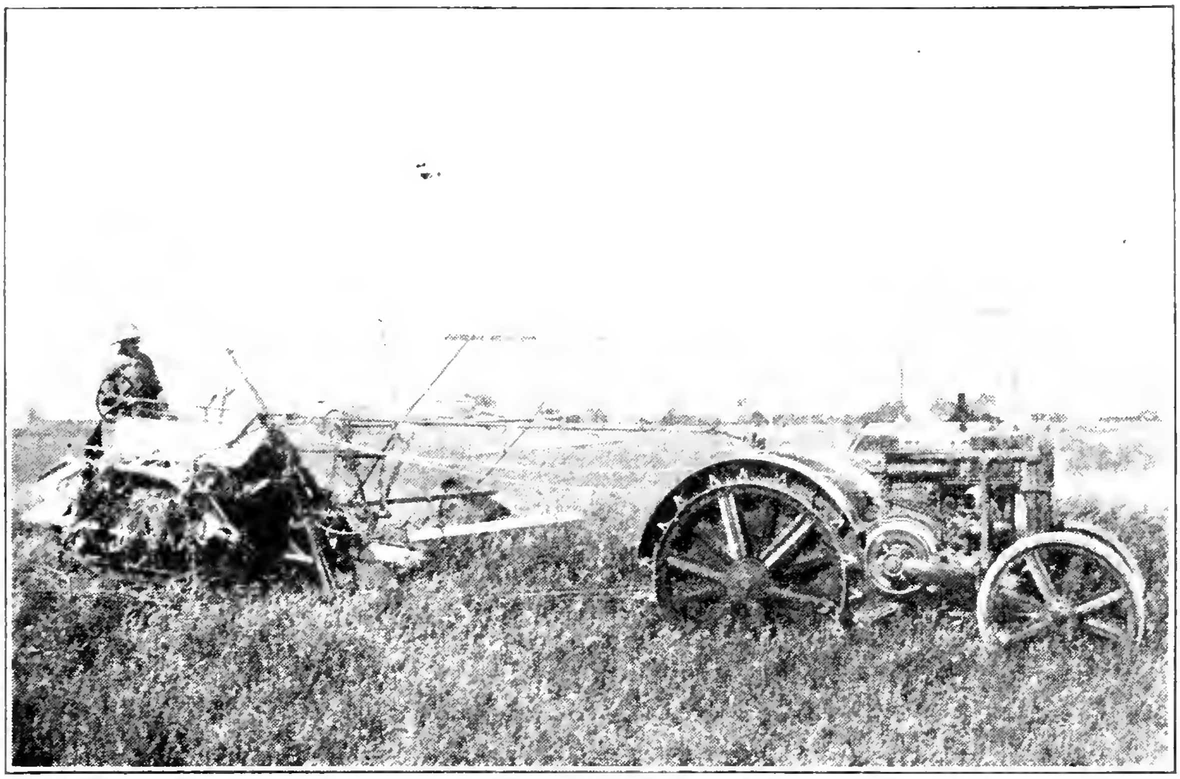
After J. I. Case Threshing Machine Co.

FIG. 376. *A gas tractor drawing a three-gang disk*

Grain-seeding machines, harrows, disks, and rollers on soils that do not pack under the weight of a small tractor have been operated extensively by tractor power, the tools being coupled together so as to dispense with the services of one man in accomplishing a given amount of work. At the present time the ordinary tractor is not generally considered as suitable for the cultivation of growing crops. Motor-driven cultivators, hoeing tools, and other implements for farm work have been placed on the market, but each has its specially designed motor attached.

During the World War the scarcity of help caused many tractors to be bought and adapted to certain lines of farming that could have been more economically performed by men and teams had the men been available.

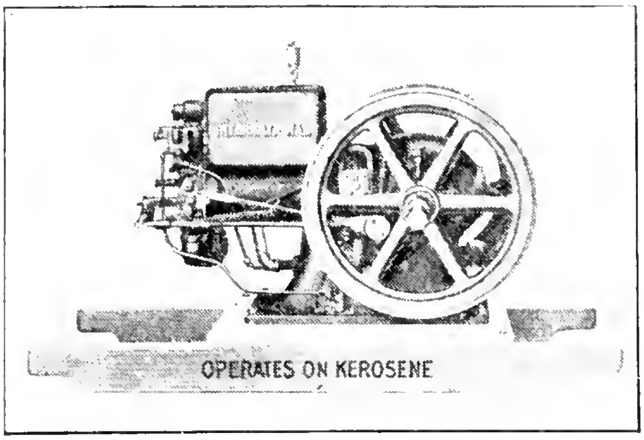
There is no tractor designed that will supply all the motive power required on a farm. In some cases the farm tractor is too large to operate economically for the power needed; in others it is essential that the work be done by horses, and a certain number of horses must be kept. Up-to-date statistics indicate that a tractor on the ordinary farm is kept in operation from twenty-one to fifty ten-hour days per year and its life is approximately eight years. It is necessary to keep on hand enough horses to perform the work that cannot be done by the tractor. *Farmer's Bulletin 1093*, United States Department of Agriculture, states that the experience of one hundred ninety-one tractor owners in the corn belt was that the number of horses kept was two or three less per farm after the purchase of the tractor, and the average acreage of land farmed was increased 22 acres. The horses kept on these farms did 75 per cent of the tractive



After J. I. Case Threshing Machine Co.

FIG. 377. *A gas tractor drawing a binder*

work, while only 25 per cent was done by the tractors. All the reports emphasized the fact that the great advantage of the tractor lies in its ability to save time at critical seasons when time is precious and the success or failure of the entire crop hangs on the speed with which it is handled.



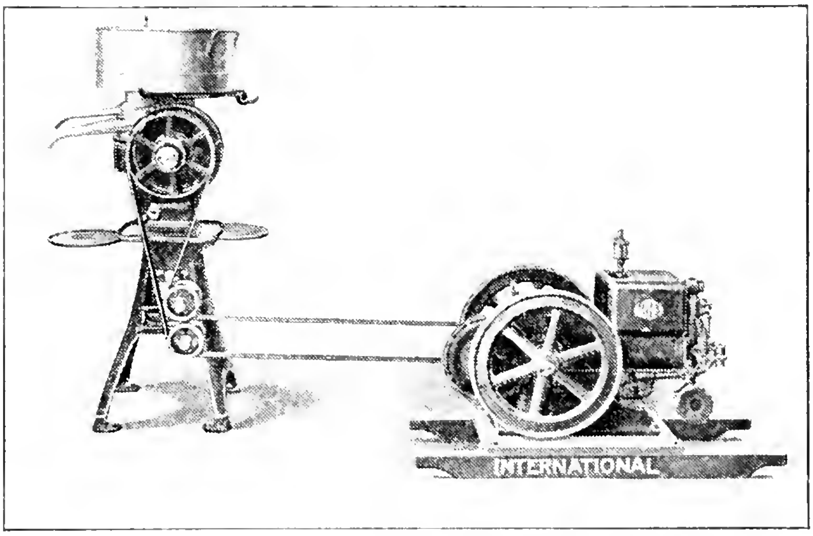
After International Harvester Co.

FIG. 378. *2½ horse power stationary gas engine*

Electric motors. Electric motors are economical only where current may be obtained from an outside source at low rates. Where it is necessary to use a gas engine to generate the electricity the work itself could better be done by the engine.

A device for converting electrical energy back into mechanical energy was soon demanded after the perfection of the electric generating machine.

Generators are rated in kilowatts and motors in horse power. Kilowatts are supplied to the motor and horse power is delivered. One horse power is, theoretically, 746 watts; a kilowatt, 1,000 watts. A kilowatt, then, is approximately 1⅓ horse power. The efficiency of motors varies greatly. The smaller the motor, the more loss. Also, the lower the voltage used, the greater will be the loss. Motors vary from 40 to 95 per cent efficiency.



After International Harvester Co.

FIG. 379. *Cream separator operated by gas engine*

The following table indicates approximately the consumption of current for different size motors operating on a 110-volt circuit:

¼ horse power, 2½ amperes, or 275 watts
½ horse power, 4½ amperes, or 500 watts
1 horse power, 9 amperes, or 990 watts
2 horse power, 17 amperes, or 1.97 kilowatts
3 horse power, 26 amperes, or 2.86 kilowatts
5 horse power, 40 amperes, or 4.40 kilowatts
7½ horse power, 60 amperes, or 6.60 kilowatts
10 horse power, 76 amperes, or 8.36 kilowatts
15 horse power, 112 amperes, or 12.32 kilowatts

It will be noted that the current consumption per horse power gradually decreases as the motor size increases.

In the care of an electric motor the following points should be noted: Provide sufficient good oil to the bearings, but do not flood with oil. Keep motor clear of dust and oil. Keep all connections tight. Do not overload motor. Protect the motor by fuses and circuit breaker.

Wind motors. A windmill is one of the oldest sources of power. Its cheapness in first cost and maintenance makes it worthy of consideration where a small amount of power is required and where time is not an element to be considered. Its use at the present time is limited almost exclusively to the pumping of water, and even for that purpose it is being superseded by the small gas engine. The windmill is liable to damage by wind and lightning during storms, and in very calm weather there may not be sufficient wind to operate it. A windmill tower should always be built high enough so that the base supporting the wheel is as high as the trees and buildings in the immediate vicinity.

The power which a good windmill will develop varies directly as the velocity of the wind, directly as the square of the diameter of the wheel, and inversely as the speed of the wheel in revolutions per minute. Calculations made on this basis are very close approximations. The above rule is deduced from a series of tests made upon various types of wind wheels. The following basis for calculation may be used: A 10-foot wheel in a 16-mile wind at 60 revolutions per minute will develop .12 horse power. To find the power which will be developed by a 14-foot wheel in a 20-mile wind at 40 revolutions per minute, proceed as follows:

$$.12 \times \frac{196}{100} \times \frac{20}{16} \times \frac{60}{40} = .44 \text{ horse power}$$

This method of calculating is amply conservative for the poorer types of wind wheels. The better types will develop up to 50 per cent more than these figures would indicate.

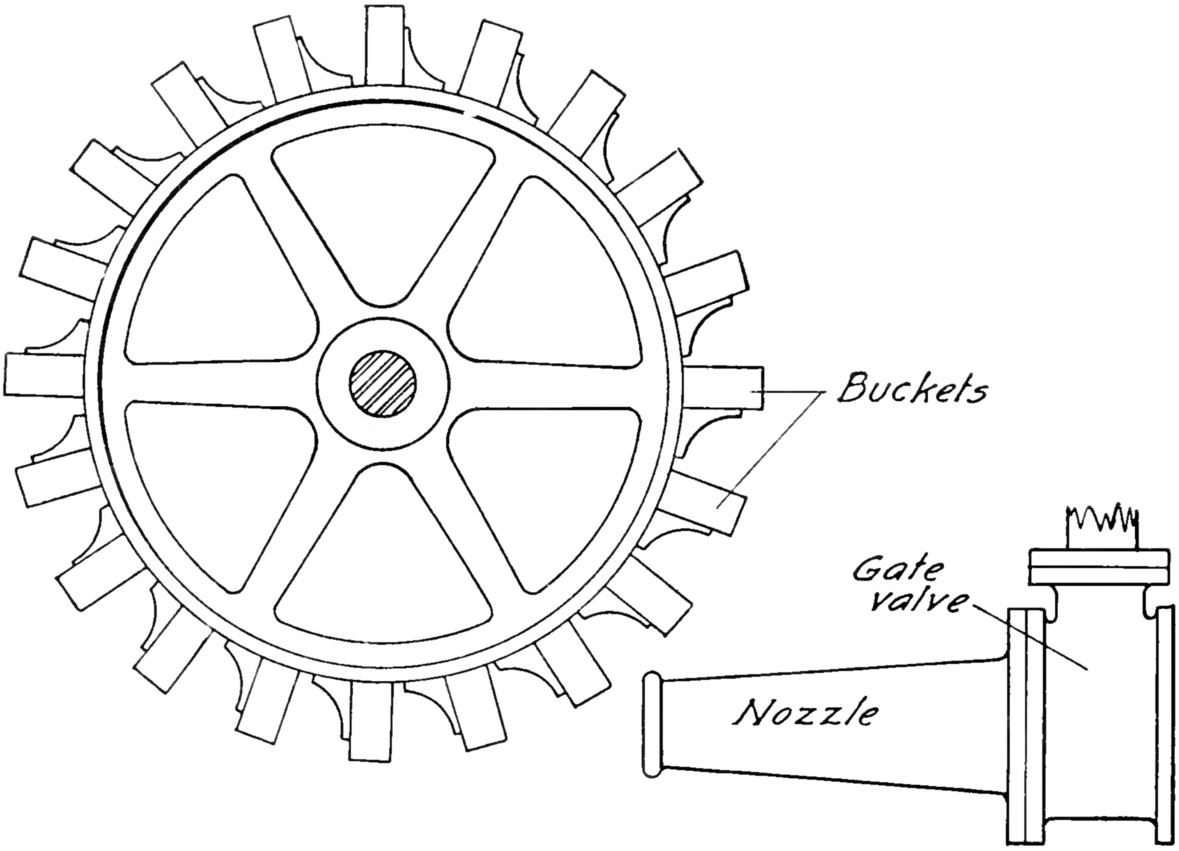


FIG. 380. *Pelton water wheel, used on high heads of small volume*

Water motors. Where flowing water is available in such quantity that dry or cold weather does not materially obstruct the flow, it may be economically used for power. The expense of dam, spillway, water wheel, and power house is usually considerably more than is required to install any other power plant. The operating cost thereafter is small.

It is important that the proper type of wheel be selected, and this is most safely handled by an engineer who is familiar with water-wheel installation. There are two types of wheels in common use, the Pelton and the turbine. In the *Pelton wheel* (Fig. 380) the water is directed against vanes or cups on the periphery of the wheel. It is used on high heads where a small quantity of water is available. The water is usually directed against the wheel through nozzles. The *turbine*

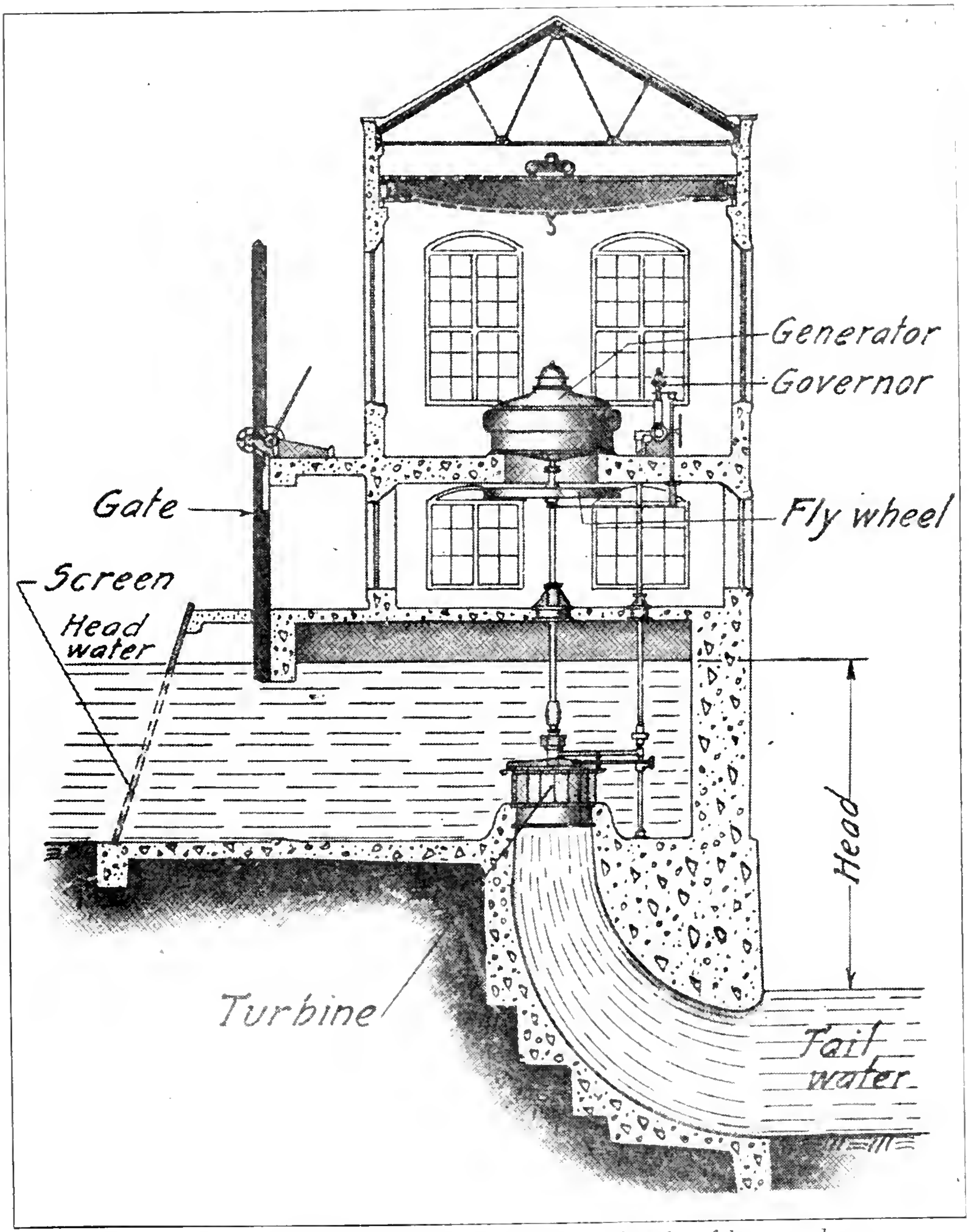


FIG. 381. *Turbine wheel, used on low heads of large volume*

wheel (Fig. 381) is a slow-moving wheel which utilizes a low head and a large volume of water.

To determine the availability of water for power purposes it is necessary to know: a suitable site for a dam, maximum fall, and second-feet of water flowing at the driest period of the year. The power available will be the cubic feet of water per minute × $62\frac{1}{2}$ × the number of feet of available fall, divided by 33,000. The efficiency of a water motor is about 75 per cent. There are many sections where a small water installation can be secured to develop from 5 to 25 horse power. First cost is large, but it is a very reliable and satisfactory source of power. When somewhat removed from the place at which the power is to be used, it can be converted into electrical energy by the use of a generator and conducted to the desired location.

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CHAPTER XXV

GAS ENGINES

Gasoline-, gas-, and oil-burning engines are called *internal combustion engines* in order that they may be distinguished from the steam engines, which also utilize the expansive power of heat, but which have the actual combustion taking place in a fire box under a boiler, separate and away from the

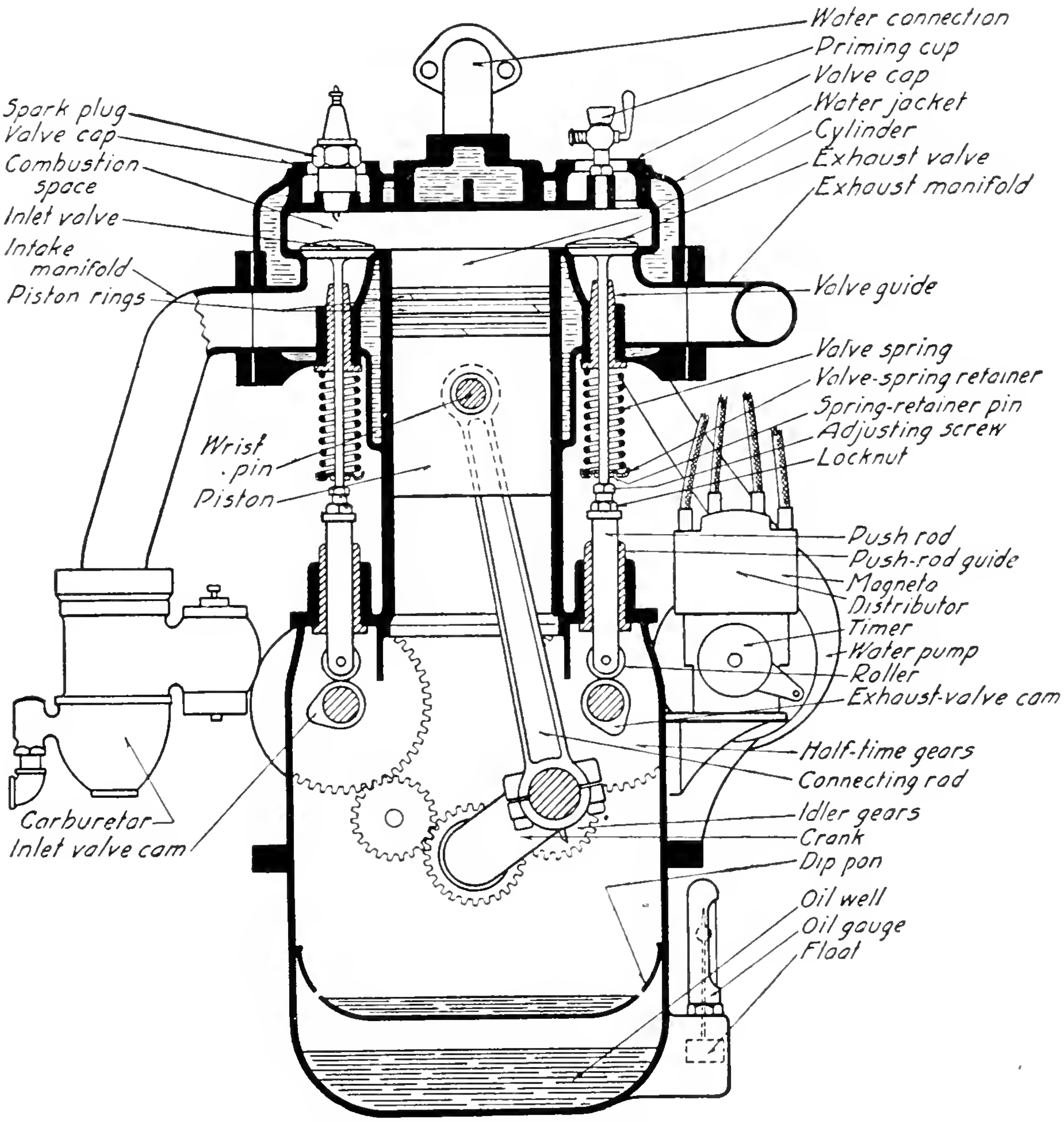

FIG. 382. *"T"-head gasoline motor showing all parts*

engine proper. A gas engine consists of a cylinder, generally made of cast iron; a piston of cast iron or aluminum alloy; a connecting rod of drop forged steel; a crank shaft of drop forged steel; a flywheel of cast iron; a frame or base of cast iron or aluminum; a fuel system, an ignition system, and provision for cooling (Fig. 382).

The fuel passes from the supply tank through a carburetor, where it is mixed properly with air, to the cylinder, in which it is fired by an electric spark. The explosion drives back the piston, and this force is transmitted by the connecting rod to the crank shaft. The flywheel serves to stabilize the running of the engine.

GASOLINE

Composition. Gasoline is the most commonly used fuel for the internal combustion engine. It is a light product distilled from crude petroleum and composed of hydrogen and carbon in the proportion of approximately 93 per cent hydrogen and 7 per cent carbon. Gasoline is offered for sale on a gravity rating on the basis of the Baume scale.

Specific Gravity	Baume Degrees	Specific Gravity	Baume Degrees
·755	56	·713	67
·751	57	·709	68
·747	58	·706	69
·743	59	·702	70
·739	60	.699	71
·735	61	.695	72
·731	62	.692	73
·727	63	.689	74
·724	64	.685	75
·720	65	.682	76
·717	66	.679	77

Gasoline as sold is known as straight-run and blended. *Straight-run gasoline* tests at the beginning 75°, at the end 60°, yielding an average of possibly 68°. A *blended gasoline* is made of naphtha or kerosene at 50° to which is added enough of 80° or 85° gasoline to make the average 68°. The difference in these two gasolines is very apparent in cold weather, although they may give about equal satisfaction during the warm weather. The difficulty with the blended gasoline is that the "tops" or high-test gasoline will evaporate in handling and in storing, leaving the less volatile fuels in excess. Volatility is the characteristic of gas-engine fuel which is at a premium.

Naphtha and kerosene are also products of crude petroleum obtained by distillation. They are heavier than gasoline, but are used as fuel in some gas engines. A special carbureting provision is necessary for their use.

GASOLINE SYSTEM

Methods of furnishing fuel to carburetor. A supply tank of a size proportionate to the demands of the engine furnishes raw gasoline to the carburetor. There are several methods of getting the fuel to the carburetor.

Overflow system. In the overflow system (Fig. 383) a double chamber is used. The gasoline supply is within reach of an engine-driven pump, which delivers more gasoline than can be used. The excess flows back to the supply tank. The overflow system is used on many small stationary engines.

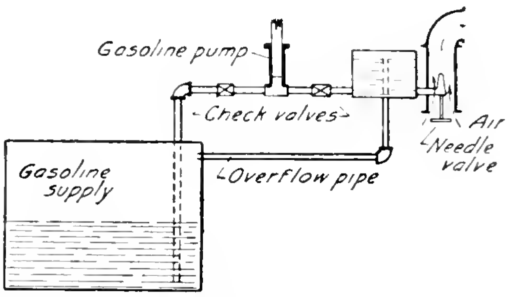

FIG. 383. *The overflow type of gasoline supply to the carburetor*

Gravity system. In the gravity system (Fig. 384) the gasoline supply is maintained above the carburetor. The carburetor is provided with a float which operates a valve regulating the flow of gasoline.

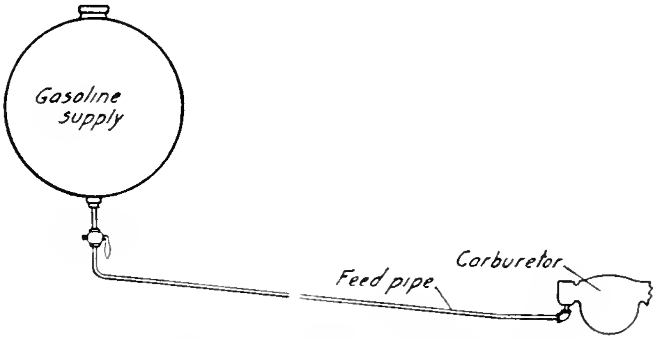

FIG. 384. *Gravity gasoline feed*

Pressure system. Where the pressure system is used, a pump is provided by which an air pressure is placed upon an air-tight gasoline tank.

This pressure forces the gasoline up the desired height, and the gasoline control is usually by means of a float and float chamber similar to that in the gravity system.

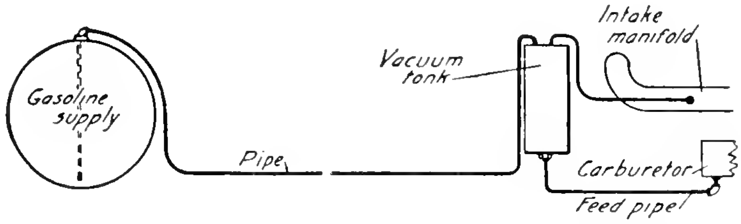

FIG. 385. *The vacuum gasoline feed system, showing connections*

Vacuum system. The vacuum system (Fig. 385) is a rather recent development. A vacuum pipe is attached to the intake manifold which provides a suction sufficient to draw gasoline from a tank 2 or 3 feet below the engine and deliver it to a float chamber. From the float chamber the carburetor is supplied as in the gravity system. The vacuum system permits the placing of the gasoline tank in a position that is both convenient for filling and safe with reference to fire. Only a small quantity of gasoline is maintained in the vacuum system float chamber, and this is warmed.

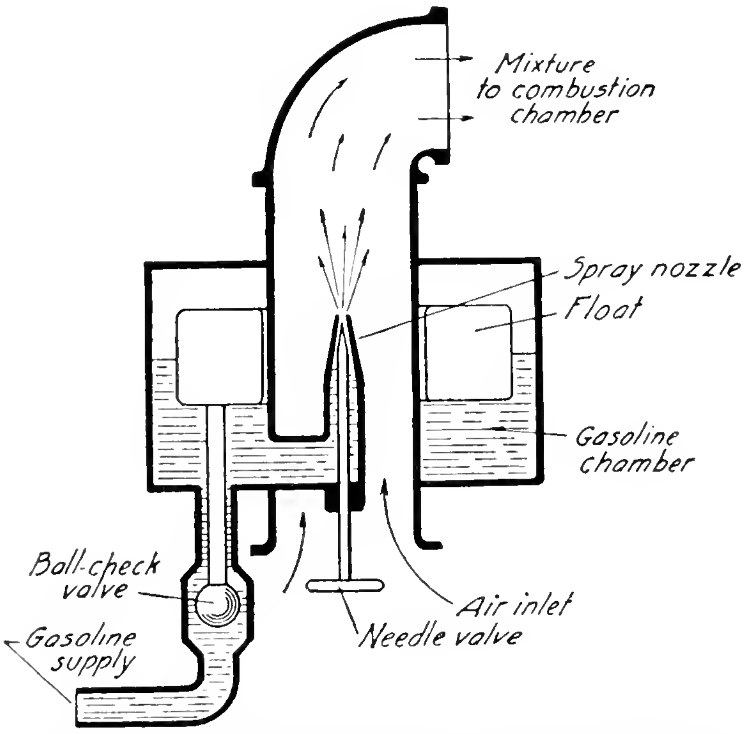

FIG. 386. *Showing the parts of a spray-nozzle or atomizer carburetor and their relative positions*

Carburetor. A *carburetor* is a device for vaporizing volatile fuel and mixing this vapor with the proper quantity of air. It requires a large proportion of air to burn vaporized gasoline completely. The best mixture is produced by 62 to 70 cubic feet of air to 1 cubic foot of gasoline vapor. The vaporizing of the gasoline is accomplished by decrease of the pressure, increase of the surface exposed, increase of air movement, and the application of heat.

The essential parts of a simple carburetor are: bowl, float, check valve, needle valve, and butterfly valve, or throttle. The more elaborate types may have additional parts, such as auxiliary air, preheater for air, preheater for fuel, macerater to aid in mixing, and superheater.

The carburetor universally used is the spray-nozzle or atomizer type (Figs. 386, 387). In the beginning of the internal-combustion engine manufacture, a good quality of fuel was available, engine speeds were slow, and little attention was paid to economy of operation. The carburetors used were of the "surface" and "overflow" types. These utilized but one of the principles of evaporation—exposure of the fuel to a column of air. While these types are no longer manufactured, the surface and overflow principles are incorporated in many of the atomizer carburetors to facilitate starting. The operation of the standard carburetor is about as follows: A chamber is supplied with gasoline which is maintained at a constant level by a float

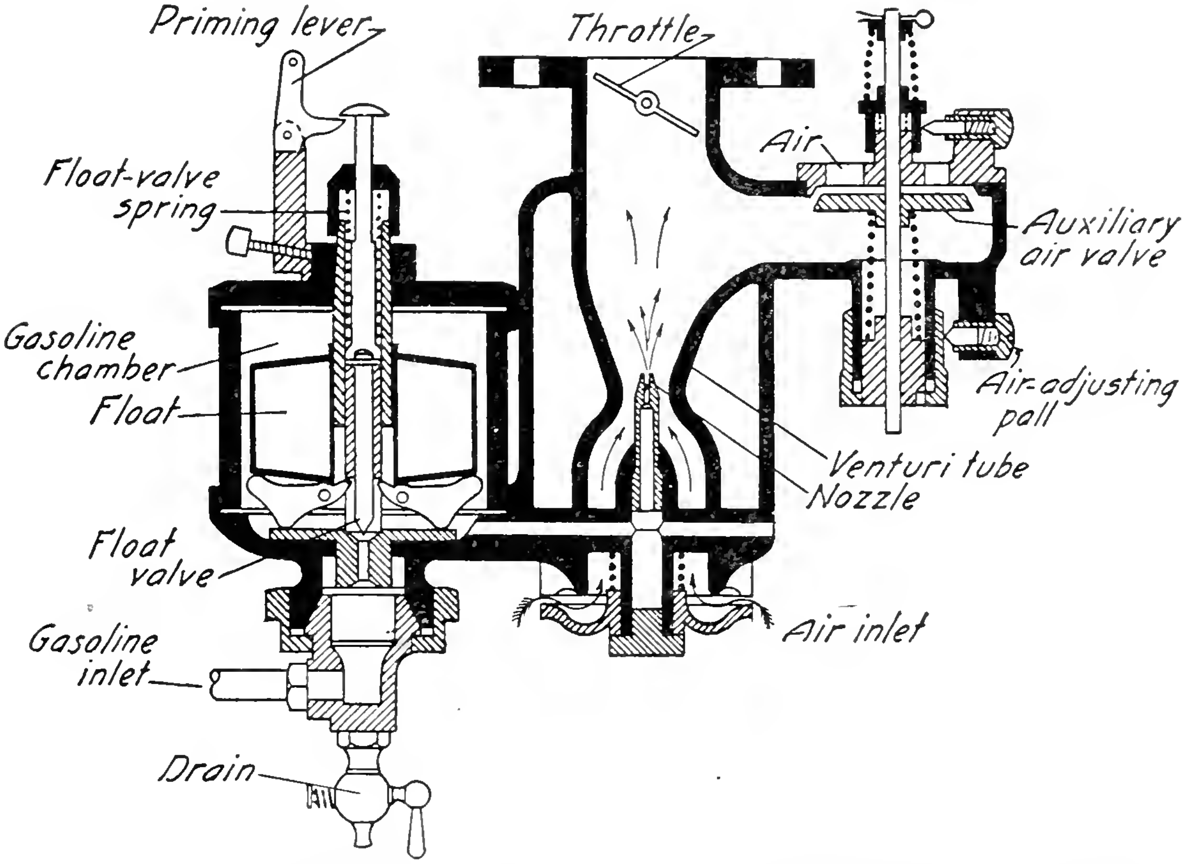

FIG. 387. *A commercial carburetor of the spray-nozzle type (Stromberg)*

or overflow provision. The level of the gasoline is adjusted so that it stands at the mouth of a small opening called the needle valve or spray nozzle. An air chamber passes directly by the orifice of the needle valve. When the air is moved through this passage by the suctional effect of the engine piston, there is produced around the needle valve a slight reduction in pressure, which causes the gasoline to flow out of the orifice, and when the suctional effect is sufficiently strong, the oil is sprayed into a finely divided vapor and carried into the combustion chamber. If the fuel used is heavy, it is necessary to reduce the size of the air passage, thereby producing a higher velocity of air past the spray or metering tube.

Adjustment of carburetor. An ideal carburetor should require no adjustment after the engine has started and has become thoroughly warmed. Adjustment is a matter of experimentation. The desired end is to get the greatest power possible from the engine. The possible adjustments involve the fuel or the air or both. Too lean a mixture will be evidenced by slow speed and lack of power and sometimes a missing of explosions or backfiring through the carburetor. Too rich a mixture will be indicated by weak explosions, possible missings, and a black, sooty exhaust. Each particular carburetor has its own special procedure by which proper adjustment may be most quickly accomplished. General instructions only can be given: Open the needle valves until the engine can be started. Let the engine warm up. Then cut down the fuel until it begins to miss. Again open the needle valve until it runs smoothly. With an auxiliary air adjustment it may be possible to loosen the retention spring and allow a larger proportion of air to enter.

IGNITION

Rapidity of burning. After a charge of fuel and air has been drawn into the cylinder, it is necessary to have some reliable means by which it may be fired. It is important

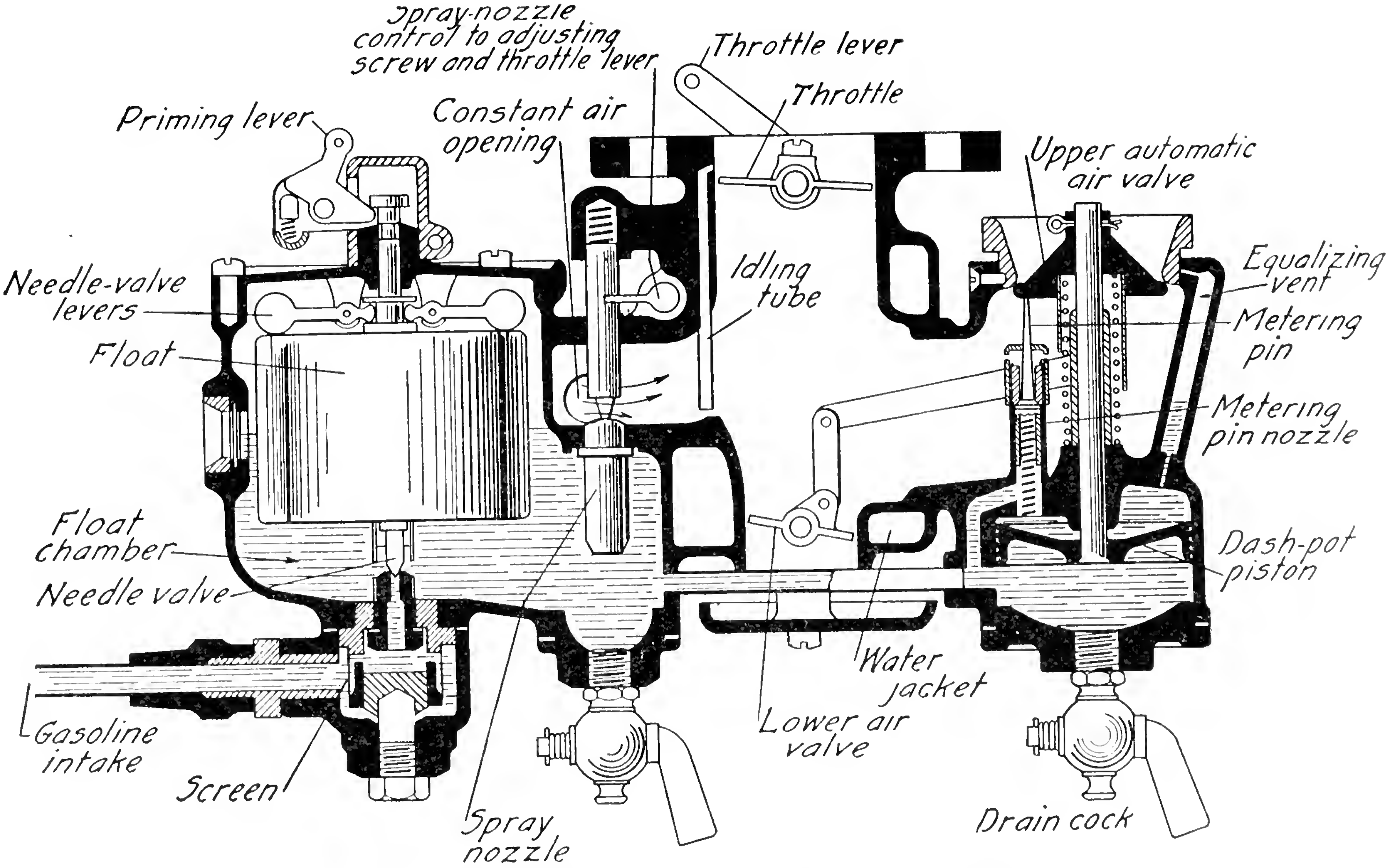

FIG. 388. *A model G (water-jacketed) Rayfield carburetor*

that it be possible to change slightly the time at which ignition shall take place in order to avoid a kick backward when the engine is turned over slowly (Fig. 389). The rapidity of burning is influenced by the shape of the combustion chamber, the timing of the ignition, the degree of compression in pounds per square inch, the quality of the mixture, the temperature of the cylinder walls, the temperature of the mixture entering the cylinder, the position of the spark plug or ignitor in the combustion chamber, and the piston speed. If there were no leakage of compression, the flame wave would travel across the combustion chamber with equal rapidity at all engine speeds. If an engine is working at approximately its maximum load, its temperature will become constant, its piston speed will remain constant, and the temperature of the incoming mixture will also remain constant. Under these conditions the position of the ignition should remain constant. If, however, any of the above conditions are changed, it will be found necessary to alter the ignition point to get the best results.

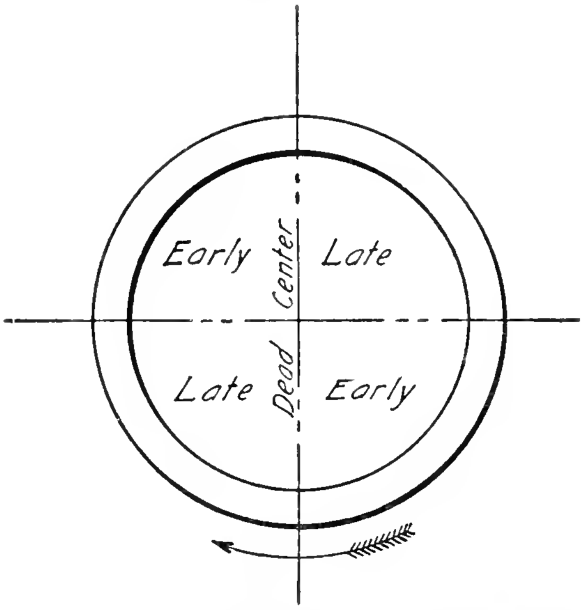

FIG. 389. *Showing the quadrants in which valves or spark may function to be designated as "early" and "late"*

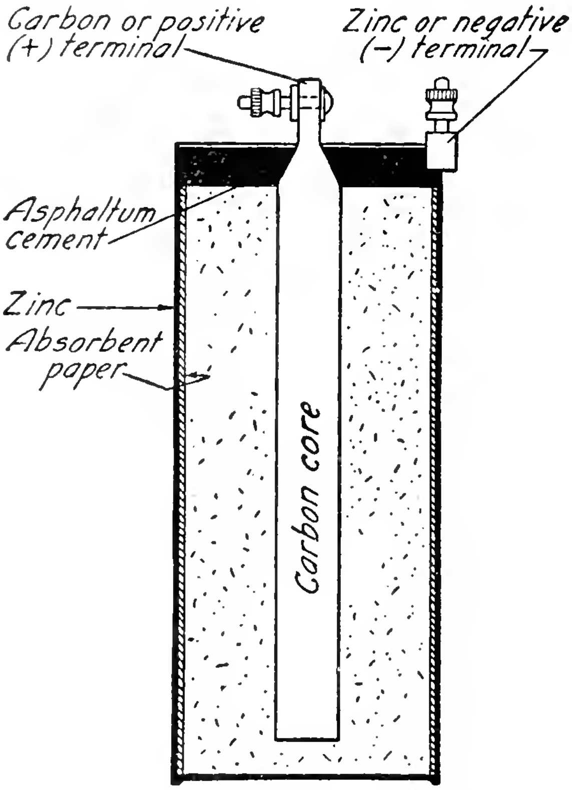

FIG. 390. *Cross section of an ordinary dry cell*

Types. The earliest types of ignition were: raw or open-flame, hot-bulb, and hot-tube. Later developments are high compression and electric-spark. Of these the electric-spark ignition only will be discussed, as it is used in all small stationary and portable engines, motor vehicles, and tractors. There are two types of the electric system, the make-and-break and the jump spark. The source of current in either system may be: primary cells (wet or dry); secondary cells (storage cells); or generators, low-voltage, direct or alternating current, or high-voltage, alternating current.

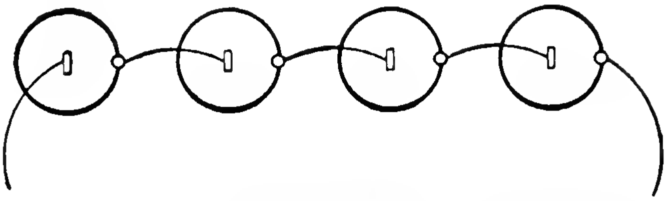
FIG. 391. *Series method of connecting dry or storage cells*

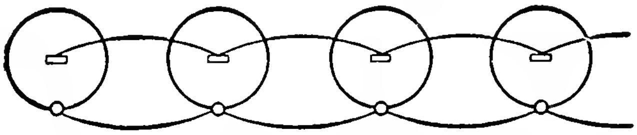
FIG. 392. *Parallel connection of cells*

Source of current. *Primary cells.* Primary cells used for ignition may be of either the wet or dry type; but the former are not extensively used because the electrolyte may be spilled and the jars or containers broken. The voltage of a dry cell (Fig. 390) is 1 to 1.5, and the amperage should be 25 to 30. A dry cell which shows above 30 amperes is generally very short-lived. The chemical action is so rapid that the zinc of the cell is quickly destroyed. Better service may be had from cells testing about 25 amperes than from those testing 30. When a number of cells are connected in series (Fig. 391), the voltage is the sum of the voltages of the several cells; when connected in parallel (Fig. 392), the resulting current has the voltage of one cell and the amperage of the sum of the cells. A combination

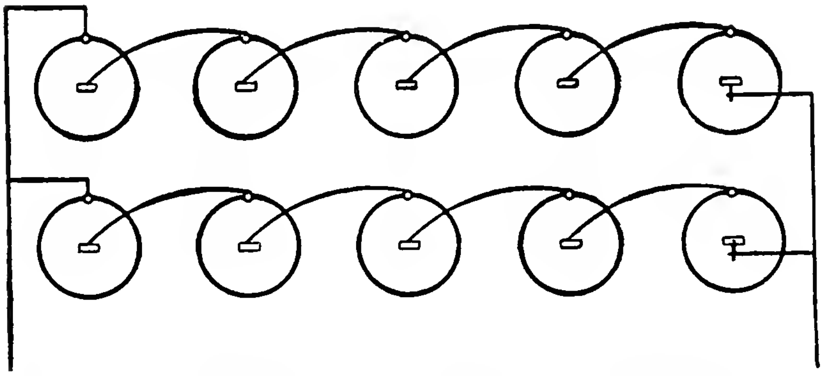
FIG. 393. *Multiple series method of connecting cells*

of the two systems, known as *multiple series* (Fig. 393), gives good results. Gas-engine manufacturers have been using 6 volts so long that it may be considered the standard ignition voltage. Tests have shown that twelve cells connected in two series of six each have much more than twice the life that would be obtained from six cells used to the limit of their life and then discarded for the other six. A poor cell connected with good cells may prevent satisfactory service, but may be replaced without serious damage having been done to the other cells.

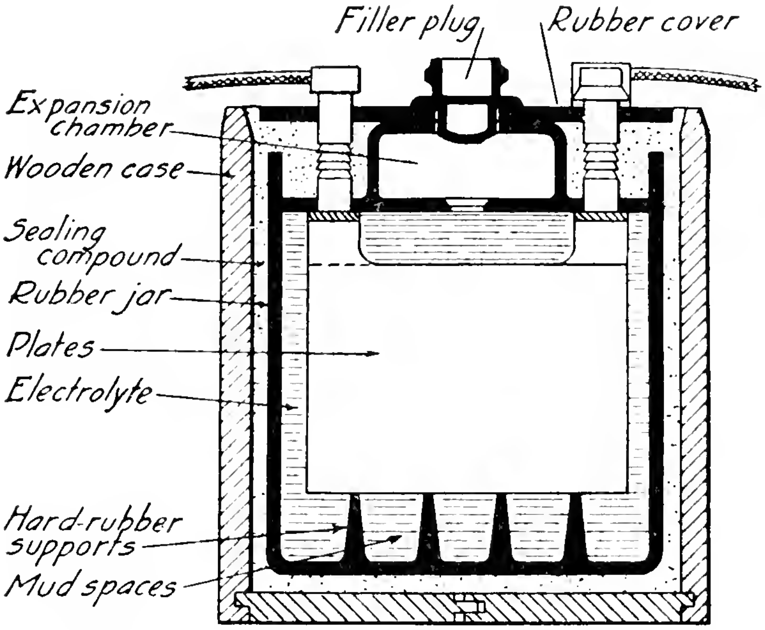

FIG. 394. *Cross section of a secondary or storage cell*

Secondary cells or storage battery. A storage cell (Fig. 394) produces about 2 volts pressure. The amperage depends upon the size and number of plates. Three storage cells connected in series deliver the 6 volts commonly used for ignition purposes. They are connected more or less permanently within a wooden case, and there is seldom occasion to disconnect them. The gravity of the electrolyte approaches 1.30 when fully charged and may drop as low as 1.15 when discharged. If it is allowed to go much below this, there is danger of damage through sulphating of the plates. The specific gravity of the electrolyte is the chief indication of the condition of the cell. While the cell is in operation, some heat is developed and some hydrogen liberated. The result is a lowering of the level of the electrolyte which must be replaced. Distilled water only should be used. Water containing any mineral adds elements which cause local action or short circuits on the plates. The result is a weakened battery or one which is entirely inactive.

When a hydrometer test shows that the electrolyte has a gravity approaching 1.15, the battery should be recharged. A direct current only may be used for this purpose. In storage batteries the rate at which they should be charged is stamped on the manufacturer's name plate. It is usually most convenient to use several ordinary incandescent lamps to secure the desired amperage. The pressure may be any voltage which is above the ultimate voltage of the battery. It may take from twenty-four to sixty hours to bring a battery up to full charge. It is exceedingly important that the direction of current from the outside source be accurately determined, since the current must go through the battery in the direction opposite to that by which the battery delivers its current. Positive of source must be connected to positive of battery. If a compass is at hand, this may be used as shown in Figure 395. Another determination may be made by means of a little of the sulphuric acid solution drawn from the cell or by acid secured from an outside source. Into a small vessel of the acid the bared terminals may be immersed. The positive terminal will show a brownish color, while the negative will be bright. A third determination may be made by immersion of the ends of the wire in a vessel containing a solution of common salt. The bubbles rising from the terminals will be oxygen from the positive and hydrogen from the negative. Since there is twice as much hydrogen as oxygen in water, the polarity will be determined by the excess of bubbles.

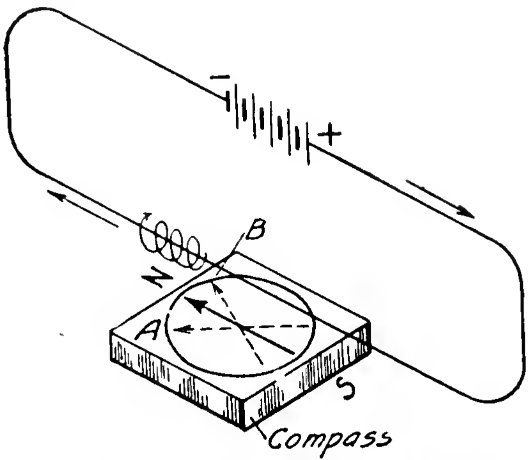

FIG. 395. *Showing the influence upon a magnetic needle of the field surrounding a conductor when the needle is brought within range. The position "A" will be taken when the needle is below the conductor when the current is flowing as indicated by the arrows. The position "B" will be taken if the needle is held above the conductor*

Approximate Temperatures at Which a Lead Plate Storage Battery Will Freeze

Specific Gravity	State of Charge	Freezing Point
1.12..........	Discharged	25° F. (above)
1.16..........	One-fourth charged	0°
1.21..........	One-half charged	20° below 0°
1.26..........	Three-fourths charged	50° below 0°
1.28–1.30....	Fully charged	Will not freeze

Hydrometers are callibrated to read correctly at 70° F. If the temperature is above or below this point, the observer should correct the reading .001 for each three degrees of variation, subtracting correction when the temperature is above 70° and adding when it is below.

One of the later steps in storage-battery construction, known as the Edison storage cell, involves the use of nickel and iron in a nickel-plated container, caustic potash being used in the electrolyte. The cell delivers a pressure of only about one volt. Its activity is very much reduced in low temperature. The objections of excessive weight and acid fumes of the lead cell are, however, very effectively eliminated.

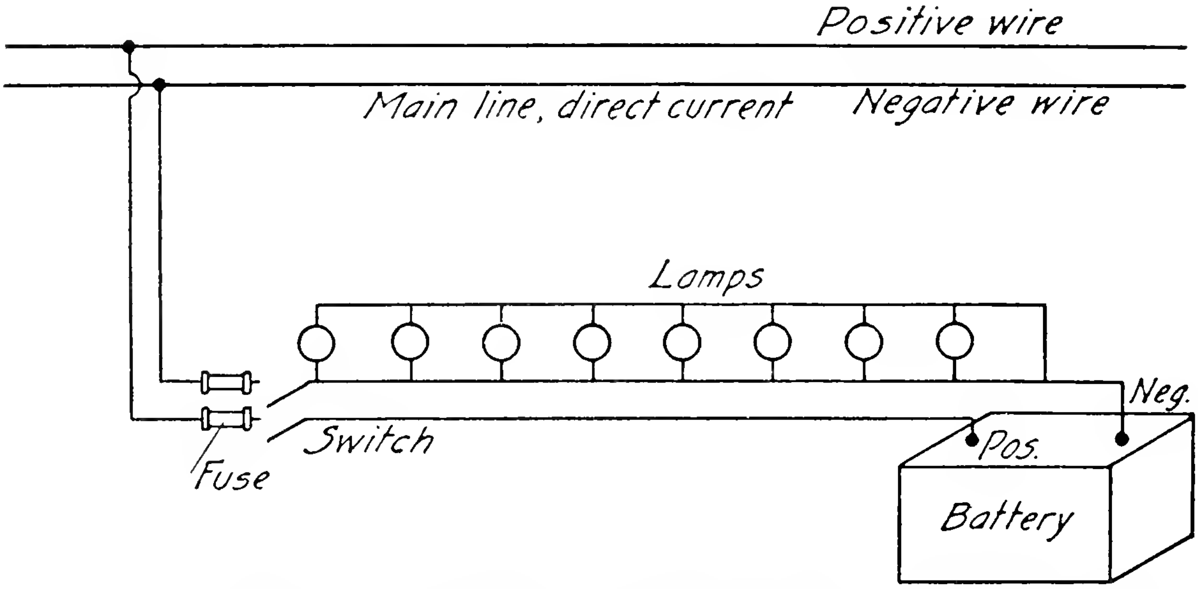

Fig. 396. *Method of connecting to an outside source of current to be used for charging a storage battery. Number of lamps used will be determined by amperage necessary to charge battery properly*

It is essential that all battery connections be clean and tight. A very small quantity of foreign matter prevents

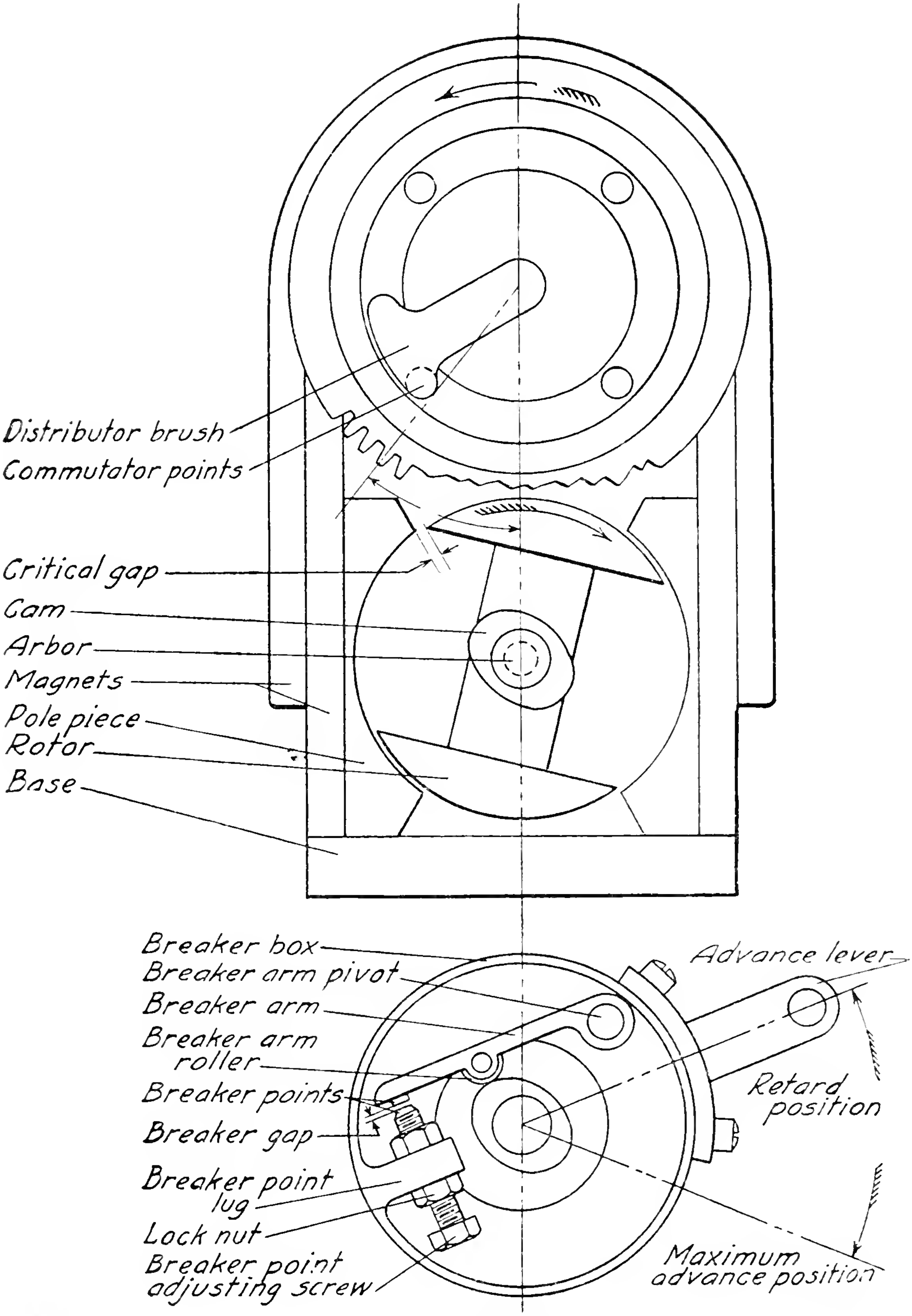

FIG. 397. *The alternating-current magneto, showing parts and critical position of the armature to get maximum spark*

proper ignition. Where possible, battery connections should be soldered to the ends of conductors so that the fastenings may be positive. Care should be taken to select a conductor sufficiently large to carry the current with a minimum of resistance. Any considerable resistance results in a heating of the conductor. This is especially important with storage batteries used for automobile starting. The amperage pulled from a storage battery by an automobile starter may be as high as 350. This strength of current calls for a large wire, as may be noted by an examination of a table of carrying capacities.

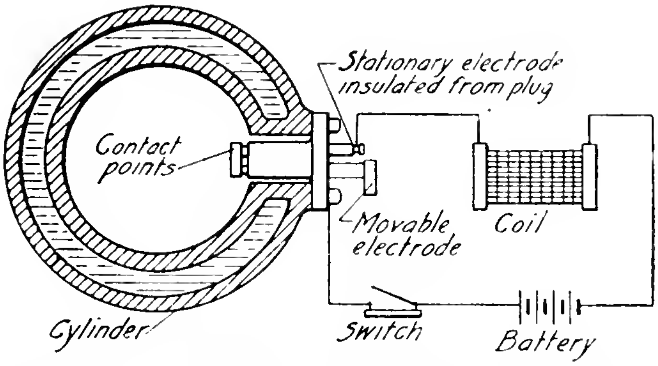

FIG. 398. *Wiring assembly as used on a make-and-break ignition system*

Magneto. The magneto (Fig. 397, page 505) is the simplest form of electrical generating machine. Several types have been used for ignition purposes: the low-tension, direct and alternating current, high-tension, and inductor. When the magneto is used on a jump-spark system, an outside breaker is necessary. On a multiple-cylinder

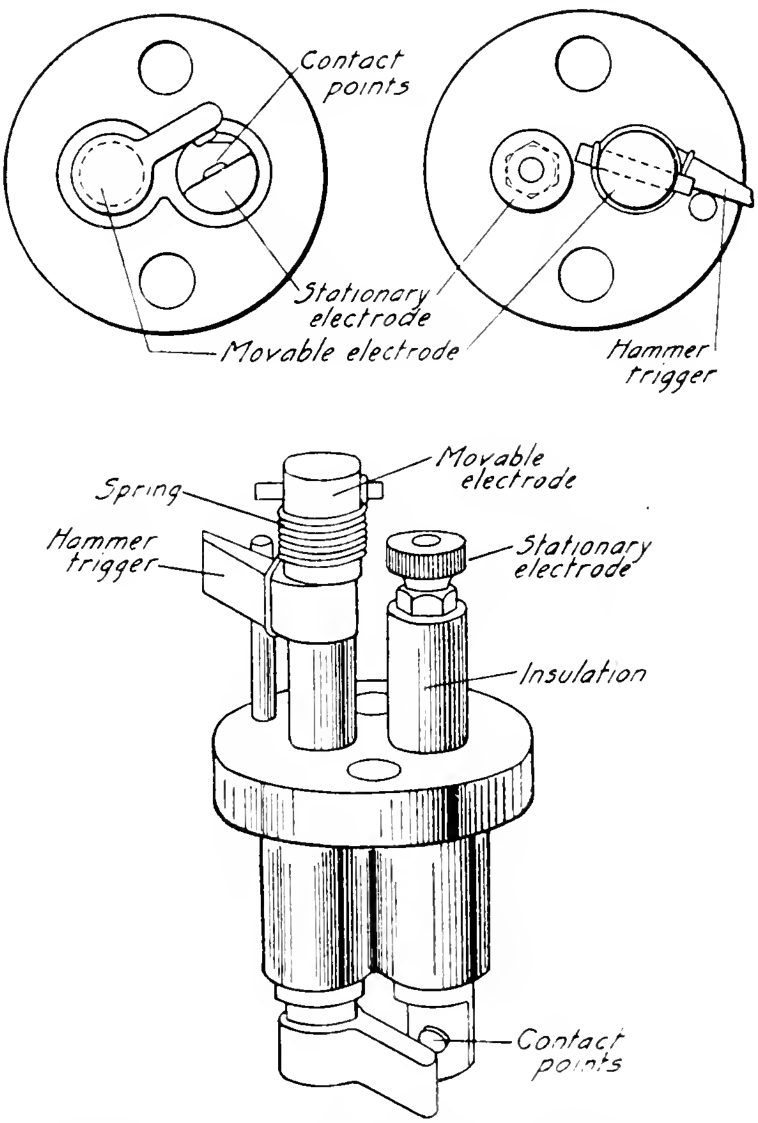

FIG. 399. *A make-and-break spark plug*

engine a distributor is used. The jump-spark system requires a high-tension or inductor type of magneto, or a low-tension current with an induction coil.

Make-and-break system. The make-and-break ignition is used on most small stationary engines and on those using a very high compression. Until recently it was regularly used on multiple-cylinder engines in racing automobiles. It is simple in construction, very reliable in operation at slow speeds, and comparatively inexpensive when it is necessary to replace parts. The essentials of a make-and-break equipment are: source of current (battery or magneto), switch, coil, and make-and-break mechanism (Fig. 398). The make-and-break mechanism must be so constructed that the

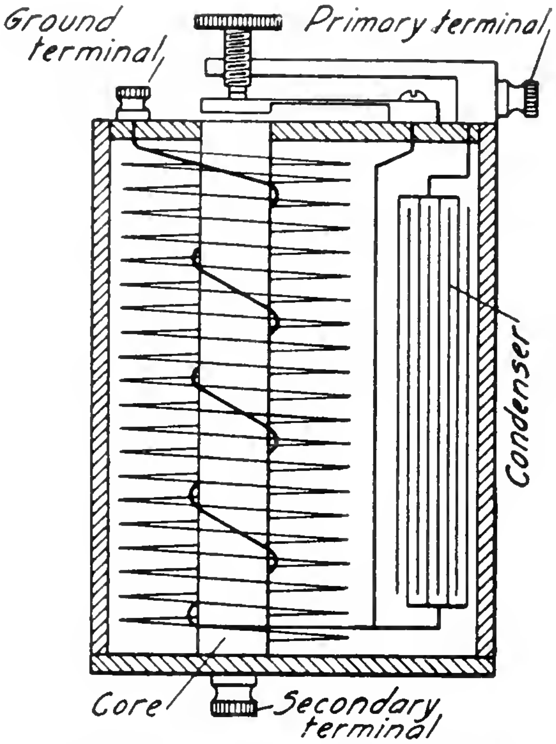

FIG. 400. *An induction or jump-spark coil, showing the connections*

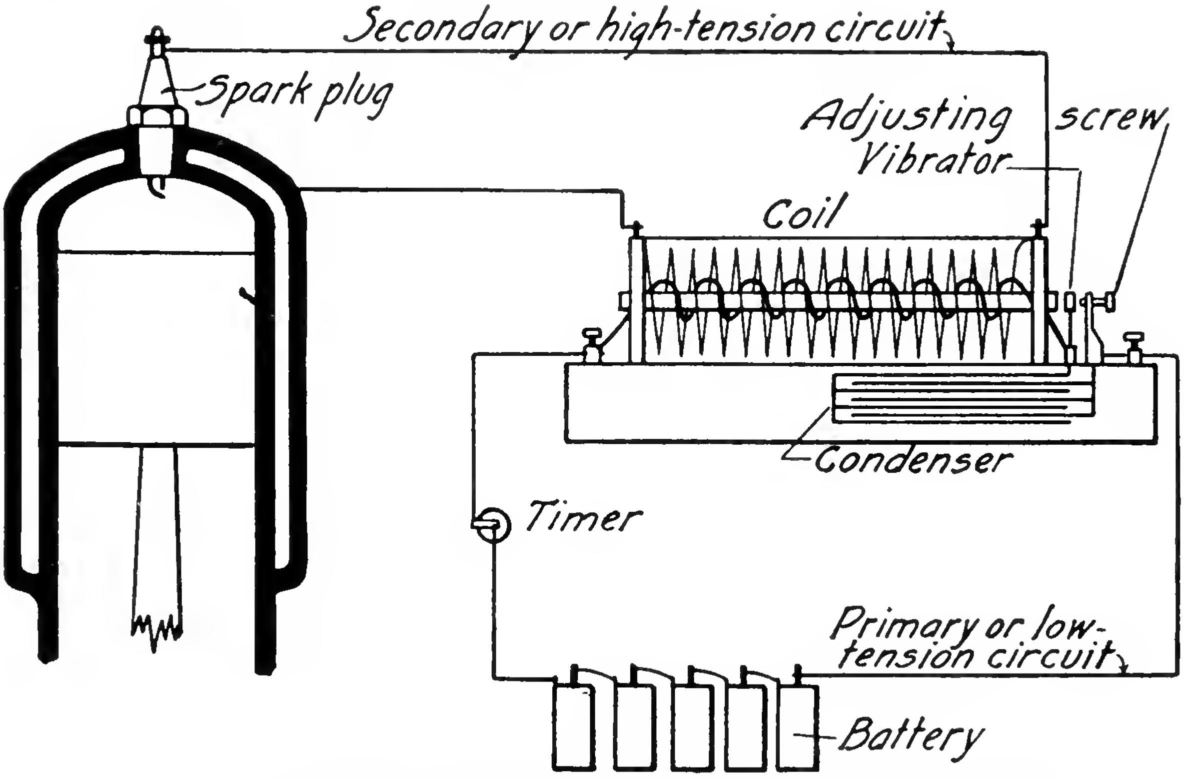

FIG. 401. *Wiring diagram for a jump-spark ignition system*

electric current may be conducted through the cylinder wall and the circuit made and broken there at the desired instant.

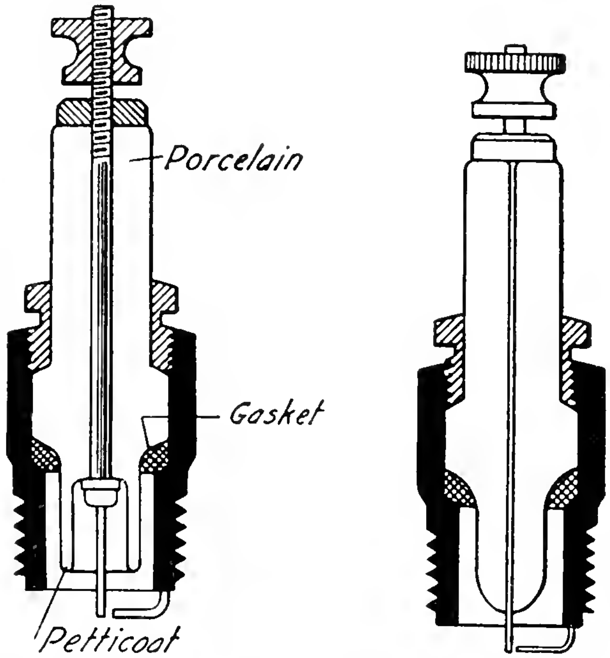

Fig. 402. *Two types of jump-spark plugs*

Jump-spark system. When engines using high speeds were developed, the make-and-break system of ignition began to show its limitations. The moving parts were heavy and noisy, and the precision necessary to exact timing was difficult to secure. The outcome was the development of the jump-spark system (Figs. 400–402). This requires: a source or current (battery or magneto), an induction coil, a circuit-breaking device, and a spark gap. The induction coil is the heart of the jump-spark system. A circuit-breaking device, which may be mechanical or automatic, is a part of the primary circuit. The induced current possesses a sufficiently high voltage to jump the small gap provided in the system. The spark gap, as usually provided, is in the form of a spark plug which has one stationary insulated terminal. The current is conducted to this terminal and allowed to jump a gap of from $\frac{1}{64}$ to $\frac{1}{16}$ inch. In the jump-spark system it is not desirable to have a spark occur at the points of the breaker in the primary circuit. To prevent this, a condenser is connected across the breaker points. The function of the condenser is to absorb the electrical energy which would otherwise produce a spark at the breaker points.

CYLINDERS

Types. The three standard commercial types of cylinders are: dome head ("I" head), ell head ("L" head), and tee head ("T" head) (Fig. 403). The designation is indicative of the shape of the combustion chamber. It has been asserted that the ideal combustion chamber is spherical. The "I" head approaches this most closely. The "L" head has one side pocket, and the "T" head two side pockets. The total combustion space is about the same in each shape. The combustion chamber in any engine may be altered by the following: thickness of the gasket between the crank case and the cylinders, or between the cylinders and the cylinder head; the quantity of carbon deposits on the walls of the combustion chamber; and the thickness of the babbit in the upper half of the connection-rod bearings. The *bore* of the engine is the diameter of the cylinder. The *stroke* is the distance between extremes of the piston travel. The *displacement* is the area of the piston head, times the stroke, times the number of cylinders. *Clearance space* or *combustion chamber* is the space above the piston, including all chambers and pockets, when the piston is at its highest point. It is usually 25 to 30 per cent of the piston displacement. The valves and spark plugs are located in the clearance space.

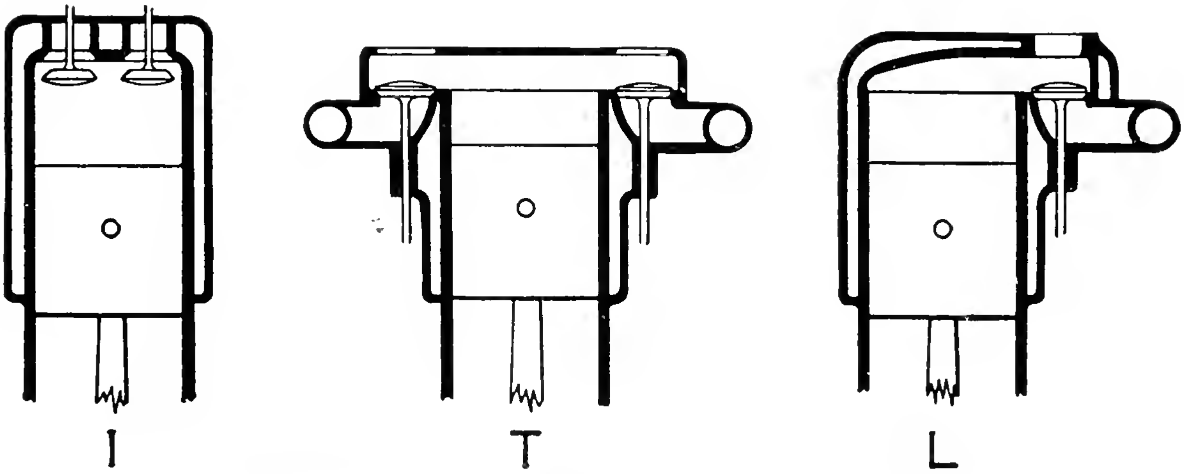

FIG. 403. *Showing the "I" or dome-head, the "T"-head, and the "L"-head cylinder construction*

CYCLE

A *cycle* is a series of operations through which a moving part passes in regular order before repeating. The most common gas-engine cycle is made up of 720° or four strokes of the piston. An engine using this cycle is known as a four-cycle or four-stroke cycle engine. The cycle strokes are by name and order: intake, compression, work, and exhaust. The cycle strokes do not coincide with the strokes of the piston. A piston stroke is 180° of crank movement. Each cycle stroke differs from the piston stroke and also from each of the other cycle strokes. The four-cycle strokes are: first, power stroke of 140° (from 0 to 140), second, exhaust stroke of 225° (from 140 to 365); third, intake stroke of 200° (from 370 to 570); fourth, compression stroke of 150° (from 570 to 720) (Fig. 404). An interval of 5° exists between 365 and 370 when all valves are closed.

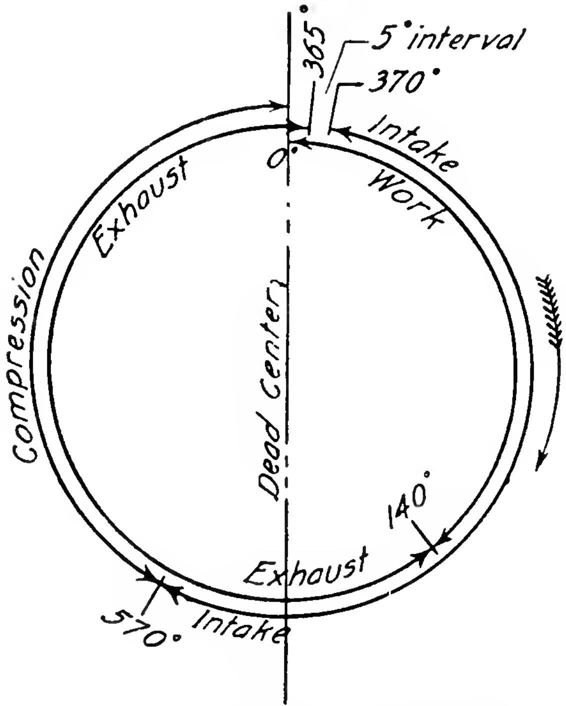

FIG. 404. *Showing the path of the crank and the relative positions of the valve timings*

At first glance the length in degrees of the cycle strokes would seem somewhat distorted. If, however, the pressures inside the piston could be examined, they would be found about as follows:

	Lb.
0	250–300
140	35– 37
180	5– 7
360	½+
365	0
370	Slightly negative
540	3 negative
570	Normal or 0
710	40–70

The aim is to get a long power stroke and still let the pressure within the combustion space come down as near as possible to normal at 180° and give but a small back pressure for the next 180. The interval of 5° is left because it would be useless to open the intake valve while there was still a positive pressure in the cylinder. The negative pressure under which the new charge is to be drawn into the cylinder must be neutralized if the largest possible quantity of mixture is to be secured. This is the reason that the intake is left open to 57o.

In a four-stroke cycle engine a power impulse is delivered every fourth stroke, and the motion of the engine must be maintained by the momentum of the flywheel covering the period of the other three strokes (Fig. 405). When a more even speed or more even *torque* (turning motion on the crank shaft) is desired, it is the practice to have more cylinders attached to the same crank shaft. Each one of the additional cyclinders has its own cycle and operates entirely independent of the other cylinders. The smoothness of operation is most effectively produced by so setting the cycles of additional cylinders that there is an even overlapping of one cycle onto the next one.

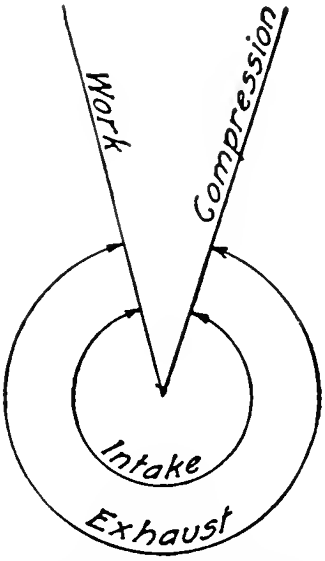

FIG. 405. *Showing the operation of a two-stroke cycle engine. This indicates the overlapping of the exhaust on the intake in the middle of the two-stroke cycle*

In a two-cylinder engine (Fig. 406), with the impulse evenly distributed, there is one power stroke for each half of the 720°, or 360°—one revolution. Two-cylinder crank shafts are made in two forms, with the cranks 180° and 360° apart. Both types are used in both the twin and the opposed engines. The crank shaft with the throws 180° apart is the standard used in two-cylinder opposed engines because the shaft is balanced naturally and it is possible to get the impulse at regular intervals of 360° of crank-shaft movement. Using a crankshaft with the throws 360° apart, it is necessary to use two cylinders side by side in order to get regular impulse. The

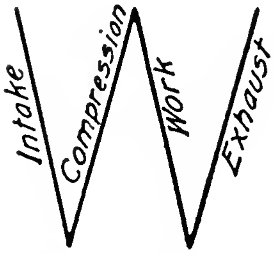

FIG. 406. *The simplest method of showing the relation of the strokes in a four-stroke cycle*

crank must be counterbalanced in order to reduce vibration. (See Fig. 407.)

A three-cylinder engine is not commonly built. It is used to a limited extent in both the two- and four-stroke cycles for marine engines. The cranks are set 120° apart.

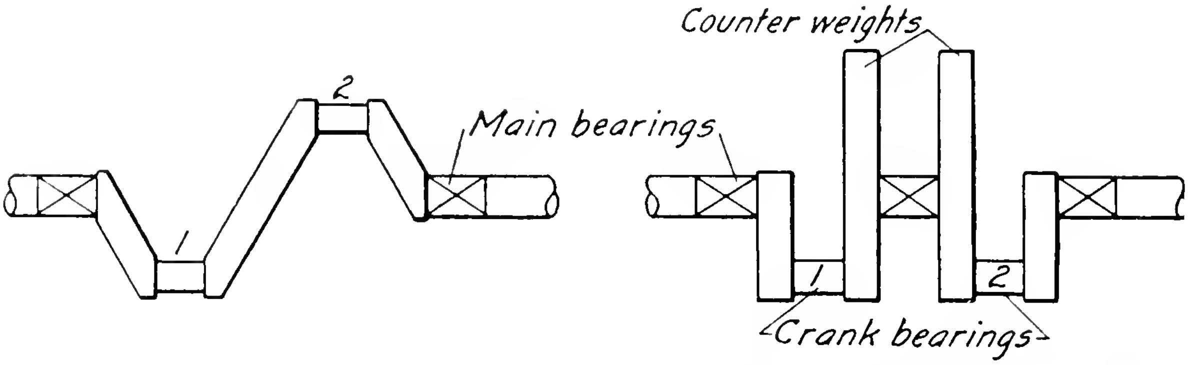

FIG. 407. *Two types of two-cylinder crank shafts. At the left the cranks are 180° apart, at the right 360° apart.*

In a four-cylinder engine (Fig. 408) an impulse is delivered each quarter of 720°, or each half-revolution. A four-cylinder crank shaft is made with 180° between the first and second throw. The second and third lie side by side and pointing in the same direction, but are considered as being 360° apart, since that is the smallest turning movement possible between impulses delivered to these two

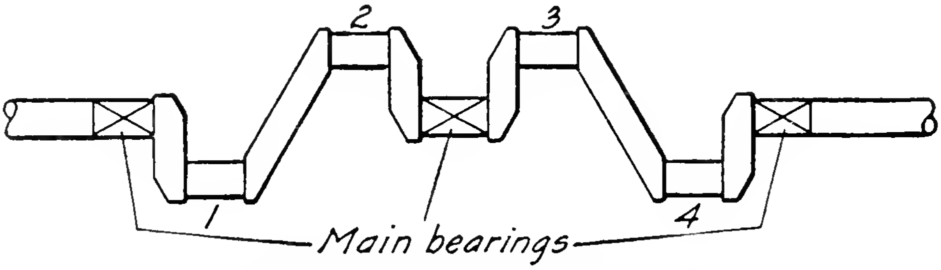

FIG. 408. *A typical three-bearing four-cylinder or four-throw crank shaft*

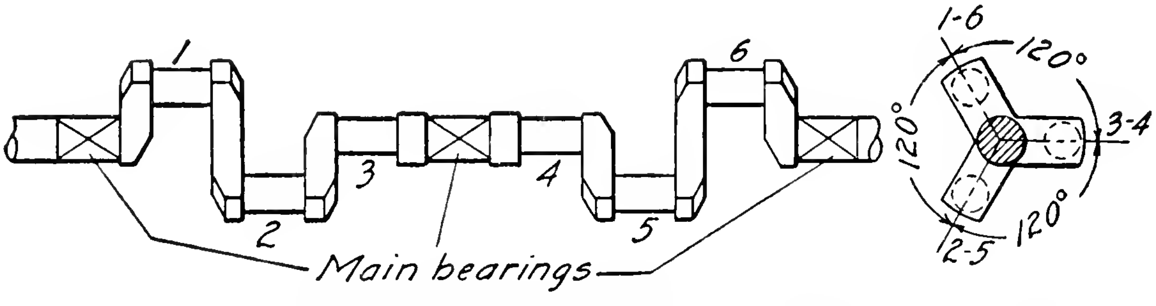

FIG. 409. *A three-bearing six-cylinder or six-throw crank shaft*

cranks. The fourth throw is 180° from two and three, and 360° from the first. It is to be noted that the four-cylinder crank shaft is very naturally balanced.

In a six-cylinder engine (Fig. 409) an impulse is delivered each sixth of 720°, or each one-third revolution. The six-cylinder crank shaft must have six throws 120° apart. As regularly made the distances are:

No. 1 to No. 2	120°
No. 1 to No. 3	240°
No. 1 to No. 4	240°
No. 3 to No. 4	360°
No. 2 to No. 5	360°
No. 1 to No. 6	360°

Nos. 1 and 6 lie in the same plane, Nos. 2 and 5 in the same plane, and Nos. 3 and 4 in the same plane. There are two types of six-cylinder crank shafts, left-hand and right-hand. In the right-hand crank shaft No. 2 is 120° from No. 1 in the direction the shaft turns. In the left-hand it is 240° in the direction of turning.

In an eight-cylinder engine (Fig. 410) an impulse is delivered for each eighth of 720°, or each quarter-revolution. The eight-cylinder crank shaft is exactly the same as the four-cylinder shaft. The additional cylinders are connected to the cranks alongside or on top of the other four connecting rods. The interpolation of the additional four cylinders is obtained by means of setting the second four cylinders at an angle of 90° to the first four.

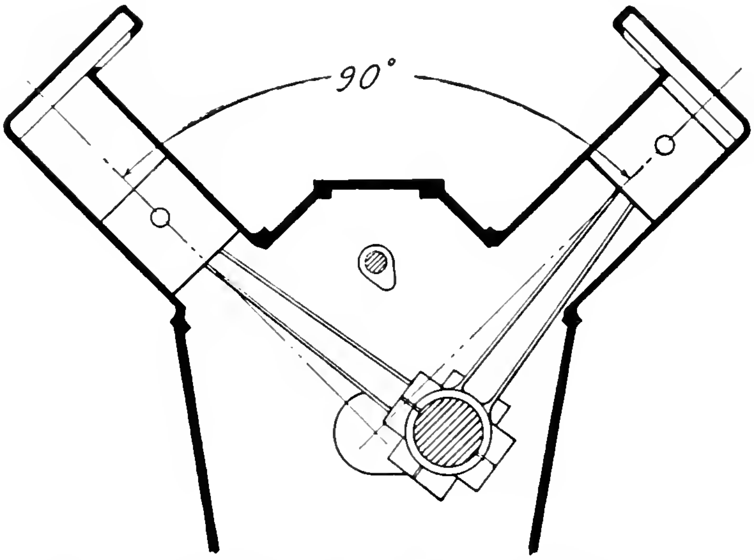

Fig. 410. *Showing relation of cylinder blocks as used in the "V"-type eight-cylinder engine*

In a twelve-cylinder engine (Fig. 411) there is an impulse for each twelfth of 720°, or each one-sixth revolution. The twelve-cylinder crank shaft is a duplicate of the six. It uses a similar type of connecting rod, and the angle between the two sets of cylinders is 60°.

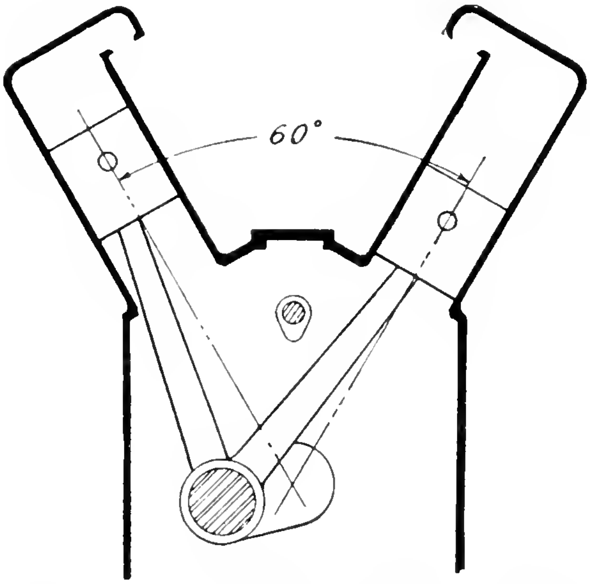

FIG. 411. *Showing relation of cylinder blocks as used in the "V"-type twelve-cylinder engine*

Order of firing. In order to issue instructions regarding the multiple-cylinder engine, it is necessary to number the cylinders. It is conventional to begin at the radiator end of the engine. The cylinder nearest the radiator will be No. 1 for the four- and the six-cylinder engines. In the 8's and 12's No. 1 is at the right next the radiator. The cylinders are numbered back in order and continue in sequence from front to rear on the left side. There are two orders of firing for a four-cylinder engine: 1-3-4-2 and 1-2-4-3. There are two orders of firing found in left-hand crank shaft six-cylinder engines: 1-2-3-6-5-4 and 1-5-4-6-2-3; and for the right-hand crank shaft: 1-3-2-6-4-5 and 1-4-5-6-3-2. An eight-cylinder engine may fire: 1-8-2-6-4-5-3-7; 1-8-2-7-4-5-3-6; 1-8-3-6-4-5-2-7, or 1-8-3-7-4-5-2-6.

Dead center. An engine is on *dead center* when the center of the piston, the center of the crank shaft, and the center of the crank pin are in a straight line. There are two such positions. *Incenter* is the dead center when the crank pin is nearest the cylinder. *Outcenter* is the dead center when the crank pin is farthest from the cylinder.

VALVES

Types and adjustment. The most common type of gas-engine valve is the poppet or mushroom valve. A *poppet* *valve* is one that opens in the direction of its length. The *rotary valve* has been used to a very limited extent. Trouble is encountered in properly cooling and lubricating this type of valve. The slide valve, as used in a steam engine, has been modified for gas-engine use and is known as the *sleeve valve*. This mechanism uses two cast-iron sleeves which move up and down immediately outside the piston. The sleeves have holes or ports which are so placed that they register at the desired piston positions. Valves are placed vertically, horizontally, and at an angle. The vertical position is probably the most common, as there are more vertical engines. The valves are generally operated by a cam shaft. In a four-stroke cycle engine the valves open and close once for each two revolutions of the crank shaft. The speed of the cam shaft, then, must be half that of the crank shaft. This is accomplished through a reducing gear. It is not possible to change the valve timing a great deal from that which was predetermined by the manufacturer. The cam shaft and cams are forged integral, and the gear is keyed or pinned on. A changing of the meshing of

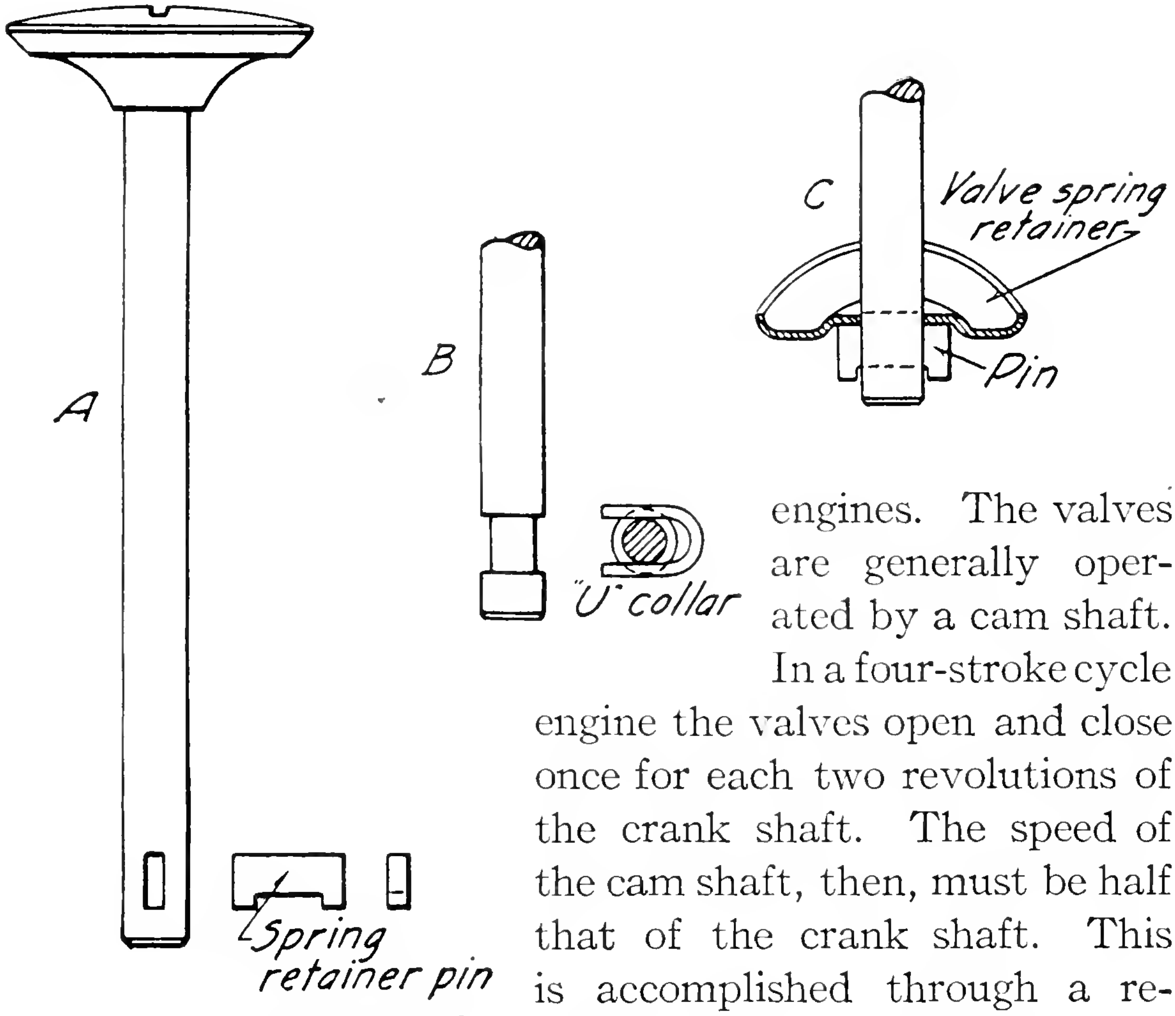

FIG. 412. *The parts which make up the valve assembly*

the gears one or more teeth will change the time of opening, but will also change the time of closing.

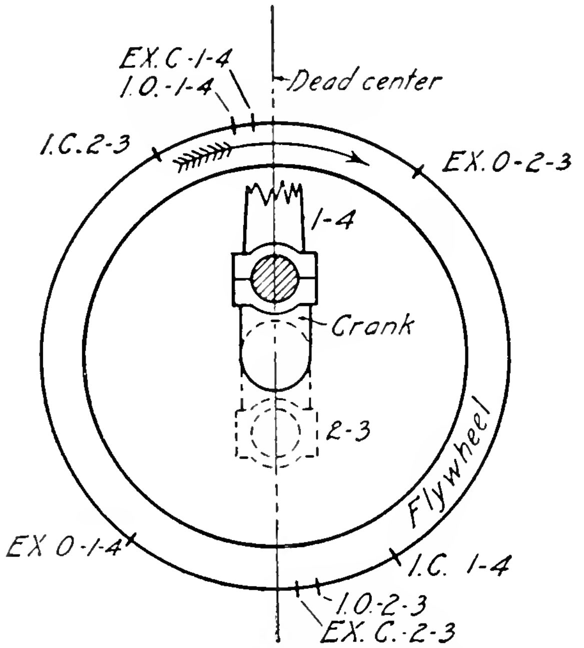

FIG. 413. *The flywheel markings as they would be found on a four-cylinder four-cycle automobile or tractor engine on dead center*

Flywheel markings. The purpose of flywheel markings is to aid the operator of a gas engine in checking up the manufacturer's intended valve timing. These markings are rather confusing to the beginner, especially in the case of a flywheel which bears the marks for the time of opening and closing for both intake and exhaust valves on a multi-cylinder engine. The markings for engines using automatically operated intake valves are comparatively simple, as only the exhausts are marked. In a mechanically operated four-cylinder engine the markings will be:

C. or D. C.	1—4	(dead center)
E. O. or Ex. Op.	1—4	(exhaust opens)
E. C. or Ex. Cl.	1—4	(exhaust closes)
I. O. or In. Op.	1—4	(intake opens)
I. C. or In. Cl.	1—4	(intake closes)

Similar markings are used for cylinders 2 and 3 at 180° respectively from these for 1 and 4. (See Fig. 413.) Since the four-cylinder crank shaft is made with cranks 1 and 4 at 360°, and with cranks 2 and 3 at 360°, the flywheel markings will be exactly the same for each pair of cylinders. Many flywheels have no valve operation markings. Some have no dead-center markings. (See Fig. 414.)

Governors. All stationary and tractor gas engines and most truck engines are supplied with a governor which automatically controls the speed. There are two types of governors: the hit-or-miss and the throttling. The *hit-or-miss governor* is used on small stationary engines where the load demands have a wide variation. Such an engine has a very heavy flywheel, which is not a good characteristic of an engine to be used in self-propelling vehicles. The governor operates by holding the exhaust valve open, by holding the intake valve closed, or by holding the exhaust valve closed and withholding the spark. The first and third methods are most common. The throttling governor has increased in popularity with

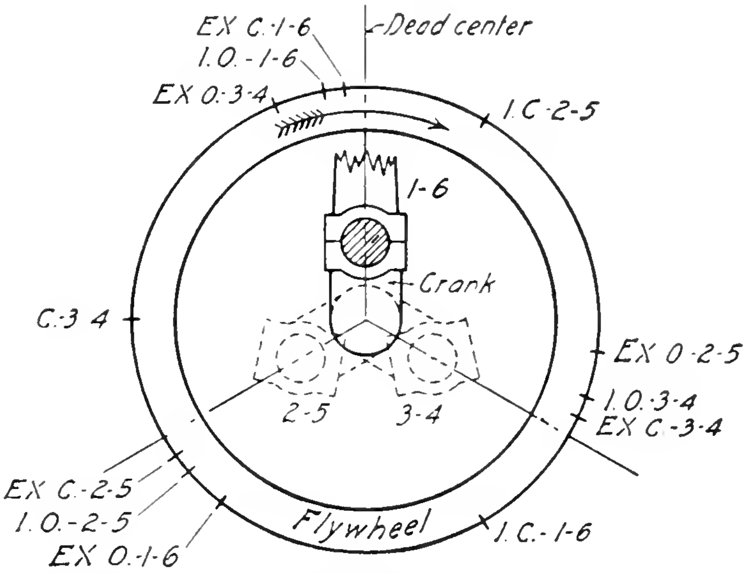

FIG. 414. *The flywheel markings as they would be found on a six-cylinder four-cycle automobile or tractor engine on dead center*

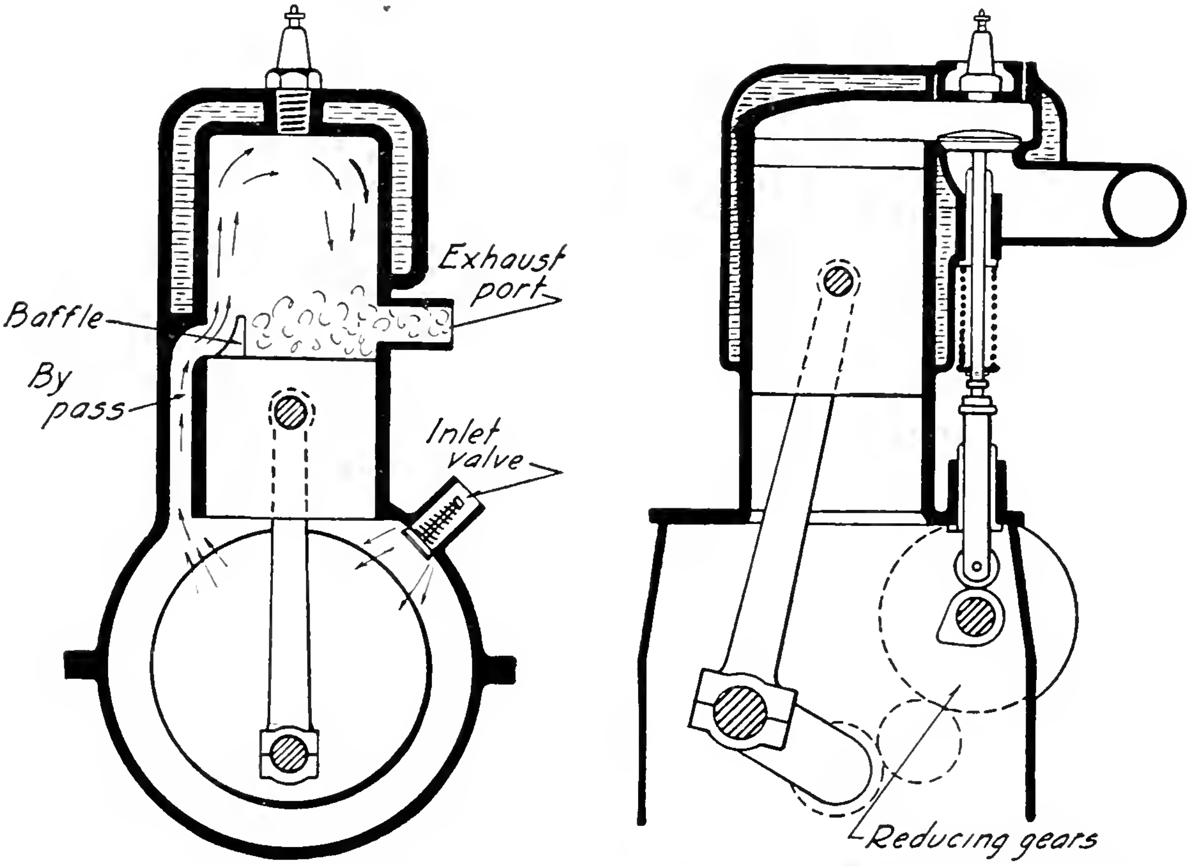

FIG. 415. *The most common design used in two-cycle and four-cycle engines*

the gradual lowering of the quality of gasoline and the desire of the engine builders to eliminate the intermittent thrust upon the crank shaft and bearings. With this an impulse is received regularly every cycle. The governor operates by reducing the quantity of mixture or by reducing the quality of the mixture — generally the first. The governing is accomplished almost entirely by the use of a butterfly valve attached to the centrifugal mechanism.

BEARINGS

The bearings used on a gasoline engine crank shaft are usually of hard babbit. The better engines are equipped with a very hard babbit with a bronze shell between the babbit and the yoke. The function of the bronze is to increase the extraction of heat developed in the babbit of the bearing. Ball and roller bearings are sometimes used on the ends of a crank shaft. All ball bearings are provided with special hardened and ground raceways.

COOLING SYSTEMS

Temperature. The temperature developed in the combustion chamber of a gas engine may run as high as 3000° F. A great deal of this heat is absorbed by the walls of the cylinder and the head of the piston. The temperature of ignition of gasoline is about 900° F. This temperature exists for a very small part of the working stroke, which makes engine cooling a problem of much less seriousness than if it were maintained for a longer period. The heat is taken from the cylinder walls by circulation of air, water, or oil.

Air cooling. Air cooling is the most simple, since it involves only the provision of fins or lugs on the external surface of the cylinder in order to increase the surface exposed and powerful fans to increase the quantity of air moved by the heated surface. A jacket surrounding the cylinder conserves the air movement from the fan and permits the removal of more heat than where the air is blown or sucked by without the aid of this jacket.

Air-cooled engines are not extensively used where a continued high duty is demanded. They work very satisfactorily where the load is light or is intermittent.

Water cooling. The most common system of cooling is accomplished by means of a double-cylinder wall with the space between filled with water. A reserve supply of water is provided and may be contained in a hopper directly over the cylinder or in a tank at some convenient place near or in a radiator. The limit of water temperature is the boiling point, or 212° F. In the hopper-cooled system the water will come to the boiling point. Continued use will make it necessary to replenish the cooling water. Where a barrel or tank reserve supply is used, the circulation between the engine jacket and the reserve may be made either by a thermo-syphon or by a circulating pump. With the circulating pump and with the radiator the reserve supply of water may be greatly reduced.

Oil cooling. Oil is used for cooling some large tractor engines, which generally run a great deal warmer than the water-cooled engines, as the oil may become much hotter than the water without evaporating and is not as thin as water, and in consequence circulates less rapidly. The oil used is a black residue from the refinery.

Cooling in winter. In the water-cooling system there is danger of the cooling water becoming frozen in cold weather. When the engine is not running, all chambers and connecting pipes should be thoroughly drained or a non-freezing solution used. Various mixtures may be made or bought which will accomplish the desired purpose, but care must be taken not to use one which has corrosive or otherwise destructive effect upon the water jacket, manifold, and radiator. A solution which attacks these surfaces is bound to give trouble sooner or later. The solution may be directly corrosive in its nature, or it may be conducive to electrolytic action just as soon as the ignition currents begin to run at random through the metal parts of the engine. All ignition systems use the metal of the engine as a part of the circuit. An anti-freezing solution may be neutralized so that it is non-corrosive and safe from electrolytic action at ordinary temperatures, but may break down and become unstable when heated to the temperatures attained in the water jacket. Alcohol with water, alcohol with water and glycerin, and kerosene are harmless and safe anti-freezing liquids.

FREEZING POINTS OF CALCIUM CHLORIDE SOLUTIONS

Per Cent by Volume of Calcium Chloride	Specific Gravity of Solution	Freezing Point
10	1.085	22° F.
15	1.131	13° F.
20	1.191	0° F.
22	1.200	−9° F.
24	1.219	−18° F.
26	1.242	−28° F.
28	1.268	−42° F.

FREEZING POINTS OF DENATURED ALCOHOL MIXED WITH WATER

Per Cent by Volume of Alcohol	Specific Gravity of Solution	Freezing Point
10	0.988	24° F.
20	0.975	14° F.
30	0.964	−1° F.
40	0.954	−20° F.
50	0.933	−32° F.
60	0.913	−45° F.
70	0.897	−57° F.

FREEZING POINTS OF ALCOHOL AND GLYCERIN MIXED WITH WATER

Alcohol and Glycerin Half and Half	Water	Freezing Point
Per Cent	Per Cent	
15	85	20° F.
25	75	8° F.
30	70	−5° F.
35	65	−18° F.
40	60	−24° F.
45	55	−30° F.
50	50	−33° F.

LUBRICATION

Selection of lubricant. The problem of gas-engine lubrication is the selection of a lubricant which will stand the high temperature of the cylinder wall and still maintain a surface film. Although the explosion temperature may approach 3000°, this drops rapidly, and it is generally agreed that the oil film on the cylinder wall is seldom exposed to a temperature higher than 700°. It does not follow that an oil must stand a temperature of 700° before burning, for it is exposed to this temperature for but a fraction of a second.

Lubrication requirements. The lubrication requirements of engines vary much more than is generally believed. When an oil is found which reaches all parts and produces a minimum of carbon in the cylinder, there is little use in trying another oil. All oils produce some carbon. The physical characteristics of a good gasoline engine oil for summer use are:

Specific gravity	28–30° Baume
Viscosity	300–400 at 70° F.
Viscosity	50–60 at 200° F.
Fire point	350°–450°
Cold point	15° above zero
Free carbon	1 per cent or less
Acid	None

For winter the cold point should be 0° or lower.

The method by which a lubricant is delivered to the surfaces is of prime importance to the engine user. All exterior journals and bearings may be provided with lubricant by oil pump, oil cup, ring oilers, chain oilers, wick oilers, or frequent hand application. Inside the crank case of a multiple-cylinder engine the problem of lubrication is handled in one of two ways, or by a combination of the two. The oldest and most commonly used is the *splash system*. In this system a pocket of oil is placed so that the crank may dip into it. The result is a splashing or throwing of the oil over the whole interior surface of the crank case, including the cylinder wall, when the piston is at the maximum "in" position. Oil gets to the cam shaft and connecting-rod bearings by flooding over the surface and leaking into the bearings. The most improved splash systems are provided with an oil pump or well from which a pump continually delivers fresh oil to the dip pan. In the *force-feed system* the crank shaft is drilled; oil is conducted to rings at one or more of the bearings of the crank shaft, whence it is forced through the hole in the crank shaft to be delivered directly to the center of the connecting-rod and crank-shaft bearings. The direction of movement of oil on the bearings in the force-feed system is from the center of the bearing outward, while with the splash system the oil works inward from the outside of the bearing. The force feed provides the surest and most efficient lubrication. Most of the better engines use a combination of the systems. In this scheme the main bearings are oiled by force with a surplus of oil. The extra oil collects in dip pans and is thrown to the piston, cylinder walls, and cam shaft.

LOCATING ENGINE TROUBLES

When an engine stops and refuses to start, attention should be turned first to the gasoline system. Leaks in the gas tank or connections may occur, or a float become "hooked up" in the carburetor or vacuum tank. Water or dirt in the gasoline may clog feed pipes, screens, or valves. Next the ignition should be carefully examined, spark plugs tested by means of turning the engine over and short-circuiting with a metal tool provided with a wooden handle, and battery connections tightened if found to be loose. When the engine is turned over to test the spark plugs, a piston which has stuck or faulty compression will be readily detected.

In case of lack of power some attention should be given to the parts above mentioned, as an obstruction in the feeding system or weak and uncertain ignition may be the source of trouble. The mixture of air and gas delivered by the carburetor should be varied and the results carefully noted. Too lean a mixture may cause missing or backfiring, and too rich a mixture weak explosions, missing, or explosions in the exhaust. After the strength of the spark has been found satisfactory, the timing may be examined. Too early a spark weakens the stroke by knocking or kicking backward, and a spark timed too late comes when the piston has already started to travel downward and the full force of the explosion is not utilized. The heat of the engine also should be watched. Overheating due to overworking the engine, late spark, rich mixture or failure in the cooling system may generate a red heat in some part of the cylinder, and this may fire the incoming gases before the proper time. Sticking or riding valves lower the power of an engine by weakening the compression in the combustion chamber, and imperfectly timed valve action has the same effect. In the cylinder parts wearing or grooving of cylinder walls or wearing or breaking of piston rings may allow some escape of gases and so decrease the power.

Specific instructions for the care of any particular type of gasoline engine will be found in the manufacturer's instruction book which accompanies a new engine or may be obtained upon application. Careful study of directions for operation and lubrication may prevent annoying delays and expensive repairs.

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THE INDEX

2 25