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Radford's Cyclopedia of

Construction

Carpentry, Building

and

Architecture

A General Reference Work on

MODERN BUILDING MATERIALS AND METHODS AND THEIR PRACTICAL AP PLICATION TO ALL FORMS OF CONSTRUCTION IN WOOD, STONE, BRICK, STEEL, AND CONCRETE; INCLUDING ALSO SUCH ALLIED BRANCHES OF THE STRUCTURAL FIELD AS HEATING AND VENTILATING, PLUMBING, ELECTRIC WIRING, PAINTING, CONTRACTS, SPECI-FICATIONS, ESTIMATING, STRUCTURAL DRAFTING, ETC.

Based on the Practical Experience of a

LARGE STAFF OF EXPERTS IN ACTUAL CONSTRUCTION WORK

Illustrated

TWELVE VOLUMES

THE RADFORD ARCHITECTURAL COMPANY

CHICAGO, ILL.

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Bibliography of Construction

BEING A SELECTED LIST OF STANDARD WORKS COVERING VARIOUS PORTIONS OF THE GENERAL FIELD OF CONSTRUCTION

In addition to the vast store of up-to-date practical information never before published, the editors have embodied in the Cyclopedia of Construction the cream of the world's best literature in this field, giving in condensed form the substance of everything essential in the experience of the past to enable the worker of the present to meet every problem likely to be met with under the conditions of ordinary practice.

For the sake, however, of those who may be interested in pursuing further study along various special lines, we furnish a list of important works that have appeared covering different portions of the field.

In this connection, the editors wish to express their thanks to American manufacturers and dealers in the machinery and materials of construction, as well as to proprietors and patentees of various special mechanical devices and processes, for valuable data, illustrations and suggestions.

Authorities on Construction

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Preface

THE Building Industry, in its various branches, is more closely identified than any other with the marvelous engineering progress of the present day and the untold possibilities of the future. To put all classes of workers in familiar touch with modern methods of construction and the latest advances in this great field, and to bring to them in a form easily available for practical use the best fruits of the highest technical training and achievement, is the service which the CYCLOPEDIA OF CONSTRUCTION aims to render.

The work is pre-eminently a product of practical experience, designed for practical workers. It is based on the idea that even in the larger problems of engineering construction, it is not now necessary for the ordinary worker in concrete, or steel, or any other form of material, to attempt the impracticable task of exploring all the highways and byways where the trained engineer or technical expert finds himself at home. The theories have been worked out; the tests and calculations have been made; observations have been recorded in thousands of instances of actual construction; and the results thus accumulated form a vast treasure of labor-saving information which is now available in the shape of practical working rules, tables, instructions, etc., covering every phase of every construction problem likely to be met with in ordinary experience. This is perhaps most apparent in the sections on *Cement and Concrete Construction, Plain and Reinforced.* To this subject, on account of its supreme importance as a structural factor of the present day, three entire volumes are devoted, embodying the cream of all the valuable information which engineers have gathered up to date. Much of this practical information now presented in this Cyclopedia, has never before been published in any form. By its use,

anyone is enabled to take advantage of the vast labors of others, and to bring to bear on any problem confronting him the results of the widest experience and the highest skill.

The keynote of the Cyclopedia is found in the emphasis constantly laid on the *practical* as distinguished from the *theoretical* form of treatment, in its total avoidance of the complicated formulas of higher mathematics, and in its reduction of all technical subjects to terms of the simplest and clearest English. Throughout the pages devoted to Steel Construction, for example, the mathematics of the subject have been eliminated to such an extent that *the reader will not find a single instance where even a square root sign has been used.*

In addition to the larger problems of engineering and building construction, one entire volume, as well as many chapters scattered through the work, is devoted to those smaller constructions that are of special interest to the teacher or student of manual training or the home shop worker of a mechanical turn of mind.

Inasmuch as a wider knowledge and a more intelligent grasp of the fundamental principles of construction and design will tend to greater efficiency on the part of workingmen, and to greater economy in production, the purpose of the CYCLOPEDIA OF CONSTRUCTION is one which will appeal strongly, not only to the men themselves, but also to the architectural and engineering fraternity as a whole.

The authors of the various sections are all men of wide experience whose recognized standing is a guarantee of reliability and practical thoroughness.

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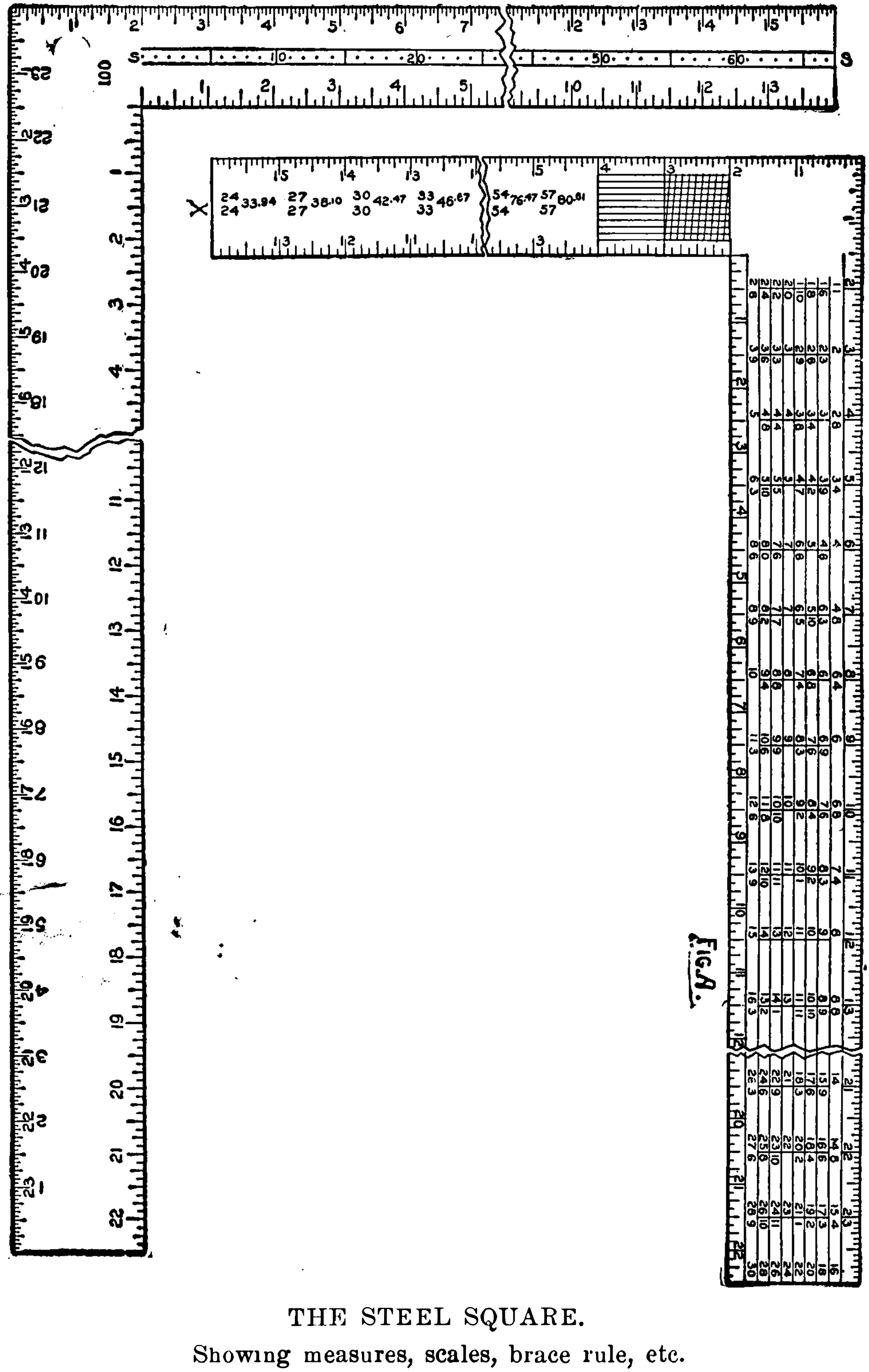

Fig. 1.

THE STEEL SQUARE.

Showing measures, scales, brace rule, etc.

The Steel Square

And Its Uses

There is nothing of more importance to a young man who is learning the business of house-joinery and carpentry, than that he should make himself thoroughly conversant with the capabilities of the tools he employs. In many instances the tools employed by the carpenter will be found to open up a far wider field of usefulness and to be adaptable to a far greater variety of purposes than the average workman is aware of. It may be that in some cases under the rules shown in this work the result can be obtained much more readily with other aids than the square; but the progressive mechanic will not rest satisfied with one method of performing operations when others which are readily available are within his reach.

In the hand of the intelligent mechanic the square becomes a simple calculating machine of the most wonderful capacity, and by it he is readily able to solve many problems of the kinds that are continually arising in mechanical work, which by the ordinary methods are more difficult to perform.

What Is Needed to Excel.—The great improvement which the arts and manufactures have attained within the last fifty years, renders it essential that every person engaged therein should use his utmost exertions to obtain perfect knowledge of the trade he professes to follow. It is not enough, nowadays, for a person to have attained the character of a good workman; that phrase implies that quantum of excellence, which consists in working correctly and neatly, under the directions of others. The workman of to-day, to excel, must understand the principles of his trade, and be able to apply them correctly in practice. Such a one has a decided advantage over his fellow-workman; and if besides his superior knowledge he possesses a steady manner, and industrious habits, his efforts cannot fail of being rewarded.

It is no sin not to know much, though it is a great one not to know all we can, and put it all to good use. Yet, how few mechanics there are who will know all they can. Men apply for employment daily who claim to be finished mechanics and profess to be conversant with all the ins and outs of their craft, and who are noways backward in demanding the highest wages going, who, when tested, are found wanting in knowledge of the simplest formulas of their trade. They may, perhaps, be able to perform a good job of work after it is laid out for them by a more competent hand, they may have a partial knowledge of the uses and application of their tools; but, generally,

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his fellow-workmen, he was forced to plod on in the same groove all his days.

Not so with the mechanic of today; if he is not well up in the minutiæ of his trade, he has but himself to blame, for although there is no royal road to knowledge, there are hundreds of open ways to obtain it; and the young mechanic who does not avail himself of one or other of these ways to enrich his mind, must lack energy, or be altogether indifferent about his trade, and may be put down as one who willl never make a workman.

The Finished Workman.—It has been thought that it would not be out of place to preface this work on the Steel Square, with the foregoing remarks, in the hope that they may stimulate the young mechanic, and urge him forward to conquer what at best are only imaginary difficulties. A willing heart and a clear head will most assuredly win honorable distinction in any trade, if they are only properly used. Indeed, during an experience of many years in the employment and superintendence of mechanics of every grade, from the green "wood-haggler" to the finished and accomplished workman, we have invariably discovered that the finished workman was the result of persistent study and application, and not, as is popularly supposed, a natural or spontaneous production. It is true that some men possess greater natural mechanical abilities than others, and consequently a greater aptitude in grasping the principles that underlie the construc-

tive arts; but as a rule, such men are not reliable; they may be expert, equal to any mechanical emergency and quick at mastering details, but they are seldom thorough, and never reliable where long-sustained efforts are required.

The mechanic who reaches a fair degree of perfection by experience, study and application, is the man who rises to the surface, and whose steadiness and trustworthiness force themselves on the notice of employers and superintendents. We have said this in order to give encouragement to those young mechanics who find it uphill work to master the intricacies of the various arts they are engaged in, for they may rest assured that in the end work and application will be sure to win; and we are certain that a thorough study of the Steel Square and its capabilities will do more than anything else to aid the young workman in mastering many of the mechanical difficulties that will confront him from time to time in his daily occupation.

Uses of the Steel Square.—It must not be supposed that the work here presented exhausts the subject. The enterprising mechanic will find opportunity for using the square in the solution of many problems that will crop up during his daily work, and the principles herein laid down will aid very much towards correct solutions. In framing roofs, bridges, trestle-work, and constructions of timber, the Steel Square is a necessity to the American carpenter; but only a few of the more intelligent workmen ever use it for

other purposes than to make measurements, lay off the mortices and tenons, and square over the various joints. Now, in framing bevel work of any description, the square may be used with great advantage and profit. Posts, girts, braces, and struts of every imaginable kind may be laid out by this wonderful instrument, if the operator will only study the plans with the view of making use of his square for obtaining the various bevels, lengths and cuts required to complete the work in hand. Tapering structures—the most difficult the framer meets with—do not contain a single bevel or length that cannot be found by the square when properly applied, and it is this fact we wish to impress on our readers, for it would be impossible in this work, to give every possible application of the square to work of this kind. We have therefore, only given such examples as will enable any one to apply some one of them to any work in hand.

Doubtless, in the early ages of mankind, when solid structures became a necessity, the want of an instrument similar to a square must have been felt at every "turn and corner," and there can be no question about one having been used—rude and imperfect perhaps—in erecting the first square or rectangular building that was ever built on this earth.

Square Used by the Earliest Builders.—The Greeks, who were an inventive people, and who were apt to ascribe to themselves more credit than was really their due, in the way of inventions and discoveries, lay claim to be the inventors of the instrument. Pliny says that Theodorus, a native of the island of Samos, was the inventor of the square and the level. Theodorus was an artist of some note, but it is evident that the square and level, in some form or other, were used long before his time, even in his own country, for some of the finest temples in Athens and other Grecian cities had been built long before his day; and the Pyramids of Egypt were hoary with age when he was in swaddling clothes.

Thus the claims made by the Greeks, to have been the originators of these two most important tools—the square and the level—we must admit, are hardly borne out under the best of authentic evidence. Indeed, the "square," as a constructive tool, must of necessity have found a place in the "kit" of the earliest builders. Evidences of its presence have been found in the ruins of prehistoric nations, and are abundant in the remains of ancient Petra, Nineveh, Babylon, Etruria, and India. South American ruins of great antiquity in Brazil, Peru, and other places, show that the

unknown races that once inhabited the South American Continent, were familiar with many of the uses of the square. Egypt, however, that cradle of all the arts, furnishes us with the most numerous, and, perhaps, the most ancient evideuces of the use of the square; paintings and inscriptions on the rock-cut tombs, the temples, and other works, showing its use and application, are plentiful. In one instance, a whole "kit" of tools was found in a tomb at Thebes, which consisted of mallets, hammers, bronze nails, small tools, drills, hatchets, adzes, squares, chisels, etc.; one bronze saw and one adze have the name of Thothmes III, of the 18th dynasty stamped on their blades, showing that they were made nearly 3,500 years ago. The constructive and decorative arts at that time were in their zenith in Egypt, and must have taken at least 1,000 years to reach that stage. Consequently, the square must have been used by the workmen of that country, at least, four thousand years ago.

The British Museum contains many tools of pre-historic origin, and the square is not the least of them. Herculaneum and Pompeïi contribute evidences of the importance of this useful tool. On some of the paintings recently discovered in those cities, the different artisans can be seen at work in their own workshops, with their work benches, saw-horses, tools, and surroundings, much about the same as we would find a small carpenter shop of today, where all the work is done by hand; the only difference being a change

in the form of the tools, which, in some instances, had been better left as these old workmen devised them.

It can make no difference, however, to the modern workman, as to when or where the square was first used; suffice to know, that at present, we have squares immensely superior to anything known to the ancients, and it may be added, that so perfect has the machinery for the manufacture of steel squares become, that a defective tool is now the exception. Of course this relates to the products of manufacturers of repute, and not to the cheap squares, or to those said to be first class, that were made ten or fifteen years ago. The tool we recommend in this book is the best made, both as to quality of material, accuracy of workmanship, and amount of useful matter on its faces.

Description of the Square.—In the foregoing sketch we have given a few hints as to the kind of square to buy; in many cases, however, this book will find its way into the hands of mechanics and others, who have old and favorite squares in their chests or workshops, and who will not care to dispose of a "well tried friend" for the purpose of filling its place with another simply because we have recommended it. To these workmen we would say we do not advise a change provided the old square is true, and the inches and sub-divisions are properly and accurately defined. We wish it distinctly understood that old squares, if true, and marked with inches and sub-divisions

of inches, will perform nearly every solution presented in this book.

The lines and figures formed on the squares of different make, sometimes vary, both as to their position on the square, and their mode of application, but a thorough understanding of the application of the scales and lines shown on any first-class tool, will enable the student to comprehend the use of the lines and figures exhibited on other first-class squares.

To insure good results, it is necessary to be careful in the selection of the tool.

The blade of the square should be 24 inches long, and two inches wide, and the tongue from 14 to 18 inches long and $1\frac{1}{2}$ inches wide. The tongue should be exactly at right angles with the blade, or in other words the "square" should be perfectly square.

How to Test the Square.—To test this question, get a board, about 12 or 14 inches wide, and four feet long, dress it on one side, and true up one edge as near straight as it is possible to make it. Lay the board on the bench, with the dressed side up, and the trued edge toward you, then apply the square, with the blade to the left, and mark across the prepared board with a pen-knife blade, pressing close up to the edge of the tongue, and then reverse the square, and move it until the tongue is close up to the knife mark; if you find that the edge of the tongue and the mark coincide, it is a proof that the tool is correct enough for your purposes.

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The Diagonal Scale.—In Fig. 1 we show a diagram of the diagonal scale enlarged and lettered for this occasion; and we may here state that the workman will find no difficulty in adapting the diagrams and what follows to the scale as depicted on his own square.

From the numerous inquiries we have had we are led to believe that the diagonal scale, of which the accompanying figure is a diagram, is not so well understood or appreciated as it ought

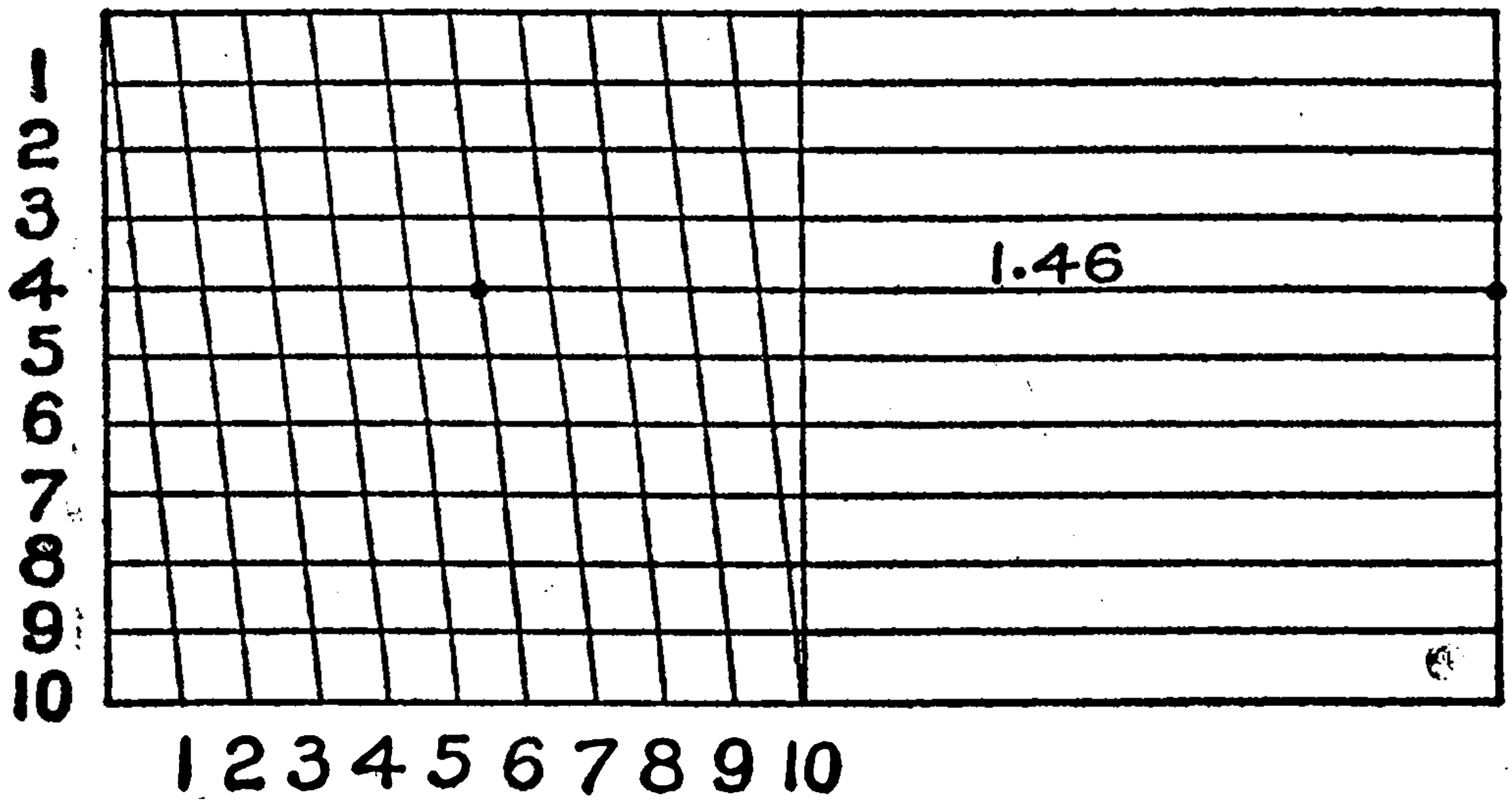

FIG. 1

to be, which is certainly to be regretted. This scale is for minute measurements, and when a thorough knowledge of its properties is understood, it is not a very difficult operation to so employ it that the 100th part of an inch may be obtained, and for practical workman this is minute enough, though to the advanced scientist this would be a trifling operation, when such minute

measurements are used as the 5000th part of an inch.

In actual practice the scale is never used to find the smaller measurements, but it may sometimes happen that the workman may want to measure a plan or take a distance on a map very accurately, then a fine subdivision will be found useful.

In order to give the reader a fair understanding of the principles on which this scale is founded, we illustrate its construction and the manner in which it is used, and in doing so, for convenience sake, quote from an excellent authority on the subject: "Let us draw a diagram Fig. 2, say three times the size of the first division of the scale as shown on the square. Imagine the short distance from A to B to represent ten inches; it will be evident to any one that to divide that short space into ten equal parts would simply confuse the whole diagram; but if we adopt another plan and divide into ten equal parts its length,

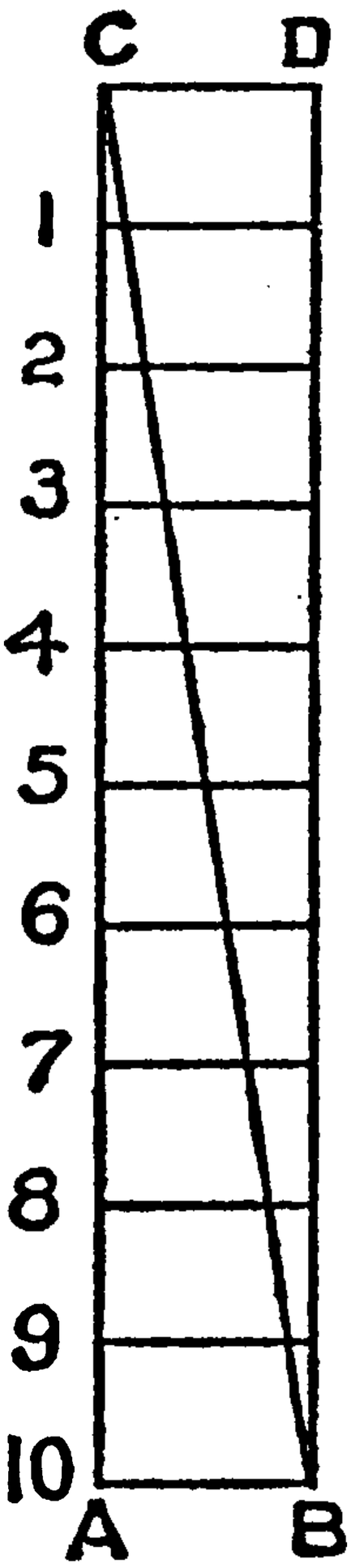

FIG. 2

as shown, and then draw a diagonal line from B to C, we have the distance AB divided into ten parts.

The numbers shown in the diagram indicate the fractional parts of the line A B, and if we take our compasses and place one leg on the line A C, at number 5, and the other leg where the diagonal

line cuts the line 5, that distance will be found to be just one-half of the distance between A and B. There is a difference of one-tenth of the whole distance between A B, at every point where the diagonal cuts the cross lines. Or in other words, where the diagonal crosses the horizontal lines, the point of juncture is one inch nearer to the line A C, than the next point lower down.

This is the principle on which the diagonal scale is based, and it will be seen that any fraction of a foot or an inch may be so divided by diagonals that the most minute subdivisions may be obtained.

The measurements, of course, are always taken along the horizontal lines, and measured from the perpendicular to the diagonal.

With a thorough knowledge of the foregoing, it will be easy to understand that the perpendicular is not necessarily limited. It may be made twice or four times the length, and divided into twice or four times the number of parts which would render the diagram to make reading of 200ths and 400ths respectively.

If twelfths of an inch or foot are wanted, all that is required is to divide the height into twelve parts instead of ten, draw the diagonal and the twelfths are there.

In using this scale let us examine it in Fig. 1, and we will see that the other divisions are in inches, so to apply the rule we proceed as follows: For instance, we want one inch and forty-six one-hundredths, place one leg of the compasses on

the one inch mark and the other leg where the diagonal cuts the line at 4, on the sixth division up. This gives the length required.

The foregoing description and explanation apply to the diagonal scale, as well as to the scale on a steel square, and generally accompanies a case of drawing instruments.

It may be well to state here that some new squares recently placed on the market, claim special features in the way of rafter tables, etc., but their scope in this direction is limited and cannot contain the general information that may be obtained from the Standard Steel Square as herein described.

Board, Plank and Scantling Measure.—Perhaps, with the single exception of the common inch divisions on the square, no set of figures on the instrument will be found more useful to the active workman than that known as the board rule. A thorough knowledge of its use may be obtained by ten minutes study, and, when once obtained, is always at hand and ready for use.

The following explanations are deemed sufficiently clear to give the reader a full knowledge of the workings of the rule. If we examine the Fig. A, in the Frontispiece, we will find under the figure 12, on the outer edge of the blade, where the length of the boards, plank, or scantling to be measured, is given, and the answer in feet and inches is found under the inches in width that the board, etc., measures. For example, take a board nine feet long and five inches wide;

FIG. 3

then under the figure 12, on the second line will be found the figure 9, which is the length of the board; then run along this line to the figure directly under the five inches (the width of the board), and we find three feet nine inches, which is the correct answer in "board measure." If the stuff is two inches thick, the sum is doubled; if three inches thick, it is trebled, etc. If the stuff is longer than any figures shown on the square, it can be measured by dividing and doubling the result. This rule is calculated, as its name indicates, for board measure, or for surfaces one inch in thickness. It may be advantageously used, however, upon timber by multiplying the result of the face measure of one side of a piece by its depth in inches. To illustrate, suppose it be required

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post and a run of the same on a girt, is 46.67 inches. The brace rule varies somewhat in the matter of the runs expressed in different squares. Some squares give a few brace lengths of which the runs upon the post and beam are unequal.

Octagonal Scale.—The "octagonal scale," as shown on the central division of the upper portion of blade, is on the opposite side of the square to the "brace rule," and runs along the center of the tongue as at S S in Frontispiece. Its use is as follows: Suppose a stick of timber ten inches square. Make a center line, which will be five inches from each edge; set a pair of compasses, putting one leg on any of the main divisions shown on the square in this scale, and the other leg on the tenth subdivision. This division, pricked off from the center line on the timber on each side, will give the points for the gauge-lines. Gauge from the corners both ways, and the lines for making the timber octagonal in its section are obtained. Always take the same number of spaces on your compasses as the timber is inches square from the center line. Thus, if a stick is twelve inches square, take twelve spaces on the compasses; if only six inches square, take six spaces on the compasses, etc. The rule always to be observed is as follows: Set off from each side of the center line upon each face as many spaces by the octagon scale as the timber is inches square. For larger timbers than the number of divisions in the scale, the measurements by it may be doubled, or trebled, as the case may be.

The diagram, Fig. 4, shows the application of the rule applied to the end of a stick of timber or on a plane surface. Let B C D E, be the square equal to six inches on a side. Draw the center lines, B C, and D E, then with the dividers

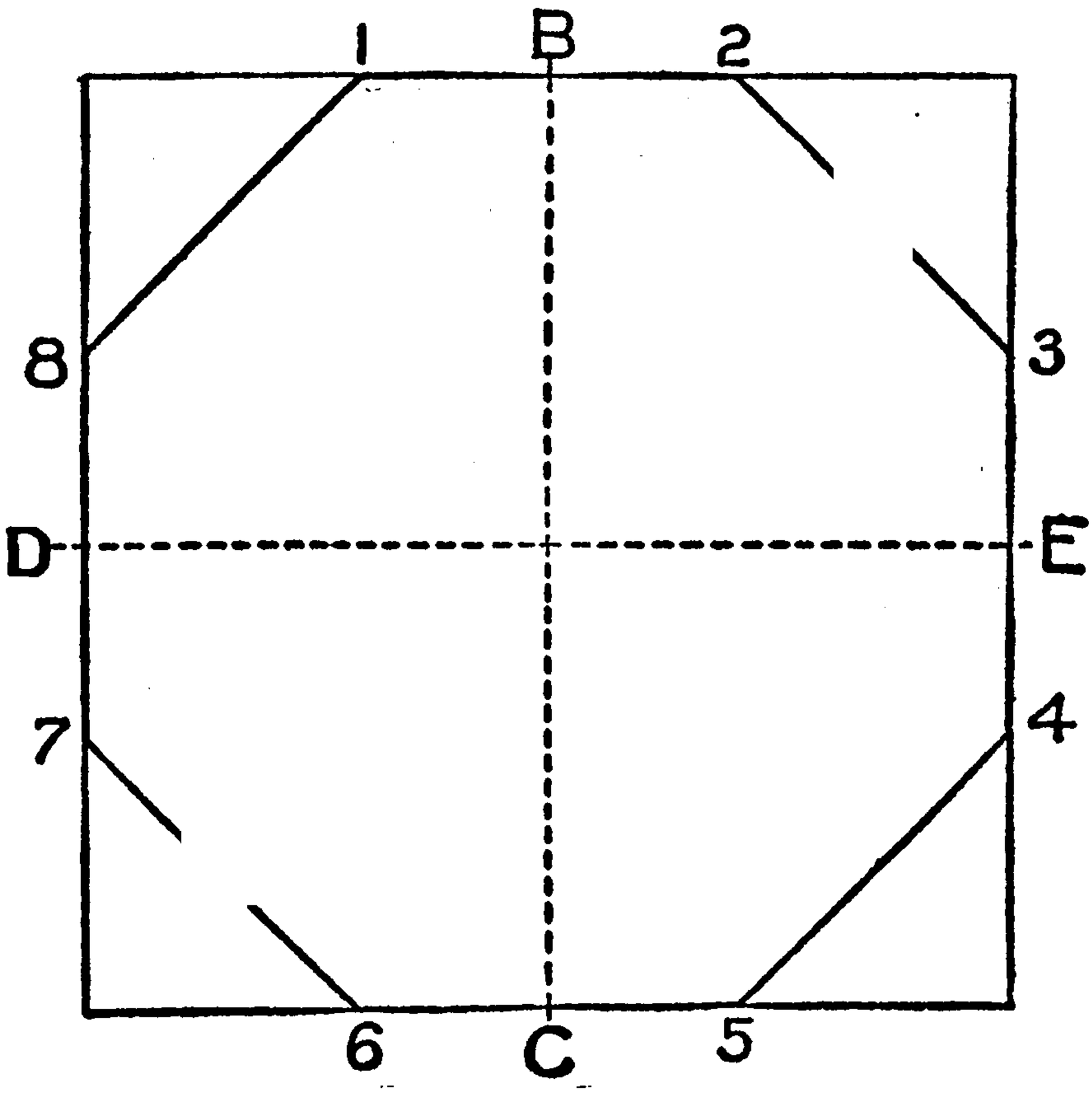

FIG. 4

take from the scale six parts, and lay off this distance from the center of each; as B1, B2, E3 and E4, C5 and C6, D7 and D8. Draw lines from 1 to 8, 2 to 3, 4 to 5, 6 to 7, and the octagon figure is complete.

A rule for laying off octagons is figured on nearly all carpenter's two-foot rules, marked off

from the inner edges of the rule; one set of figures is denoted by the letter E, another set is denoted by the letter M. The set marked E measures the distance from the edge of the square to the points indicated in the diagram, by the figures 1, 2, 3, 4, etc. The set marked M is used for finding the points 1, 2, 3, 4, etc., by measuring from the middle or center lines, B, E, C, D.

We have now fully described all the lines, figures, and scales that are usually found on the better class of squares now in use; but we may as well remark here that there are squares in use of an inferior grade, that are somewhat differently figured. These tools, however, are such as cannot be recommended for the purposes of the scientific carpenter or joiner.

The Adjustable Fence

Notwithstanding the marvelous capabilities of the steel square in itself, the functions of this versatile tool can be greatly extended by the aid of auxiliary devices and appendages.

A necessary appendange to the steel square in solving mechanical problems, is what we call, for want of a better name, an **adjustable fence.** This is made out of a piece of hardwood 2 inches wide, and 2 feet 10 inches long (being cut so that it will pack in a tool chest), and 15/8 inches thick; run a gauge line down the center of both edges; this done, run a saw kerf cutting down these gauge lines at least one foot from each end, leaving about ten inches of solid wood in

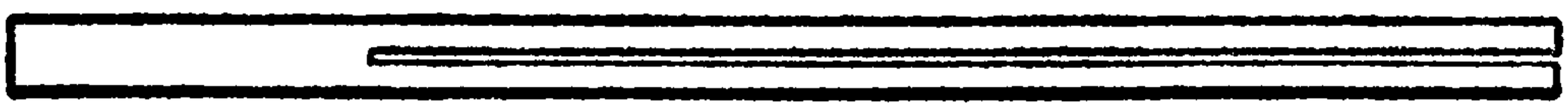

Fig 5.

the center of fence. We now take our square and insert the blade in the saw kerf at one end of the fence, and the tongue in the kerf, at the other, the fence forming the third side of a right-angled triangle, the blade and the tongue of the square forming the other two sides. A fence may be made to do pretty fair service, if the saw kerf is all cut from one end as shown in Fig. 5. The next step will be to make provision for hold-

ing the fence tight on the square; this is best done by putting a No. 10, 1½-inch screw in each end of the fence, close up to the blade and tongue; having done this, we are ready to proceed to business.

Application of the Fence.—The fence being made as desired, in either of the methods mentioned, and adjusted to the square, work can be commenced forthwith.

The first attempt will be to make a pattern for a brace, for a four-foot "run." Take a piece

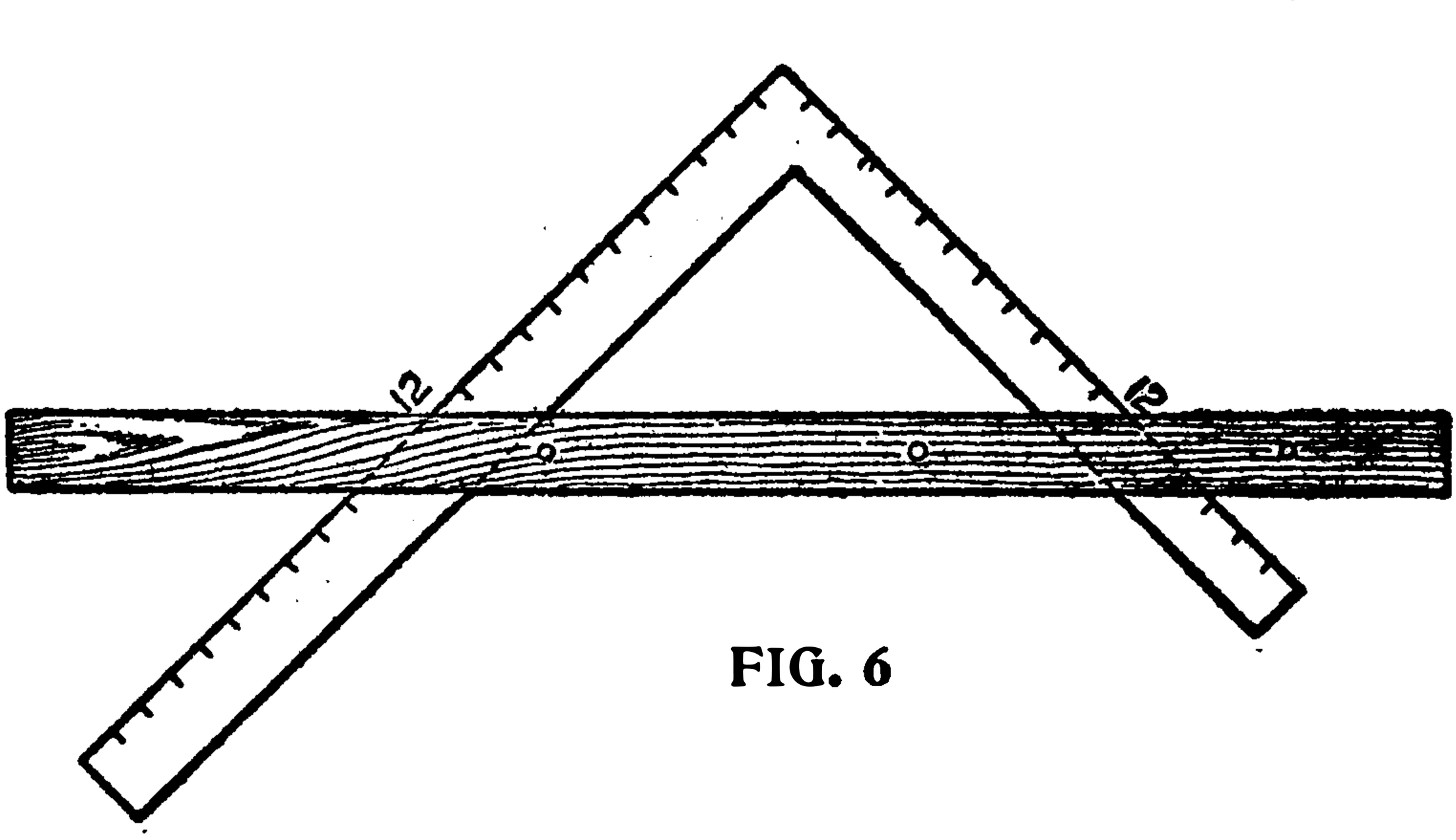

FIG. 6

of stuff already prepared, six feet long, four inches wide and a half-inch thick.

Take the square as arranged at Fig. 6, and place it on the prepared stuff as shown in Fig. 7. Adjust the square so that the twelve-inch lines coincide exactly with the gauge line 0, 0, 0, 0. Hold the square firmly in the position now obtained, and slide the fence up the tongue and blade until it fits snugly against the jointed

edge of the prepared stuff, screw the fence tight on the square, and be sure that the 12-inch marks on both the blade and the tongue are in exact position over the gauge-line.

We are now ready to lay out the pattern. Slide the square to the extreme left, as shown on the dotted lines at X, mark with a knife on the outside edges of the square, cutting the gauge-

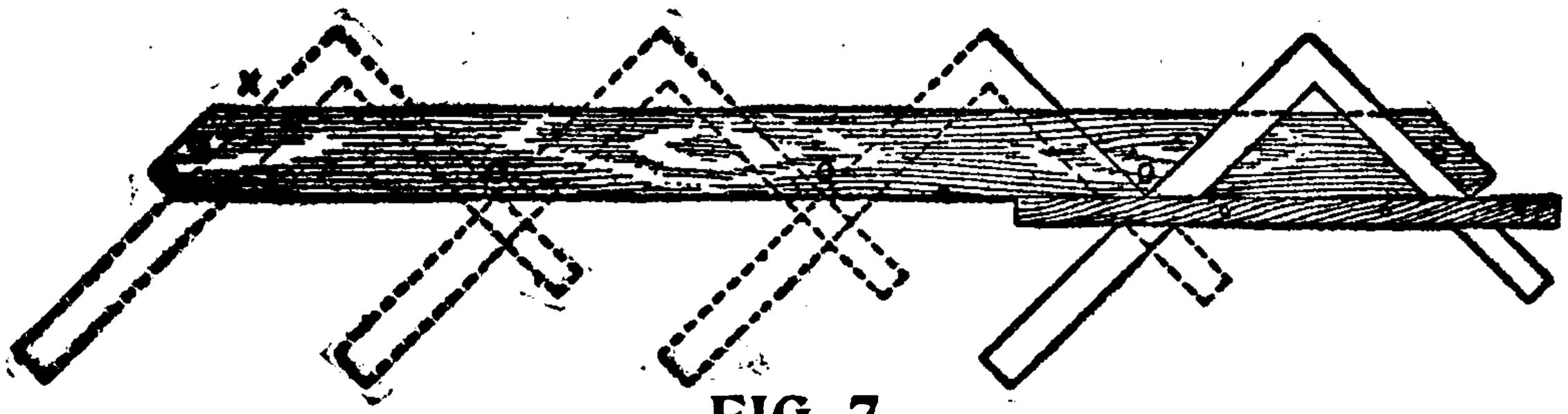

FIG. 7

line. Slide the square to the right until the 12-inch mark on the tongue stands over the knife mark on the gauge line; mark the right hand side of the square, cutting the gauge line as before, repeat the process four times, marking the extreme ends to cut off, and we have the length of the brace and the bevels.

Square over, at each end from the gauge line, and we have the toe of the brace. The lines, S, S, shown at the ends of the pattern, represent the tenons that are to be left on the braces. This pattern is now complete; to make it handy for use, however, nail a strip 2 inches wide on its edge, to answer for a fence and the pattern can then be used either side up.

Formation of a Brace.—The cut in Fig. 8, shows the brace in position, on a reduced scale.

The principle on which the square works in the formation of a brace can easily be understood from this cut, as the dotted lines show the posi-

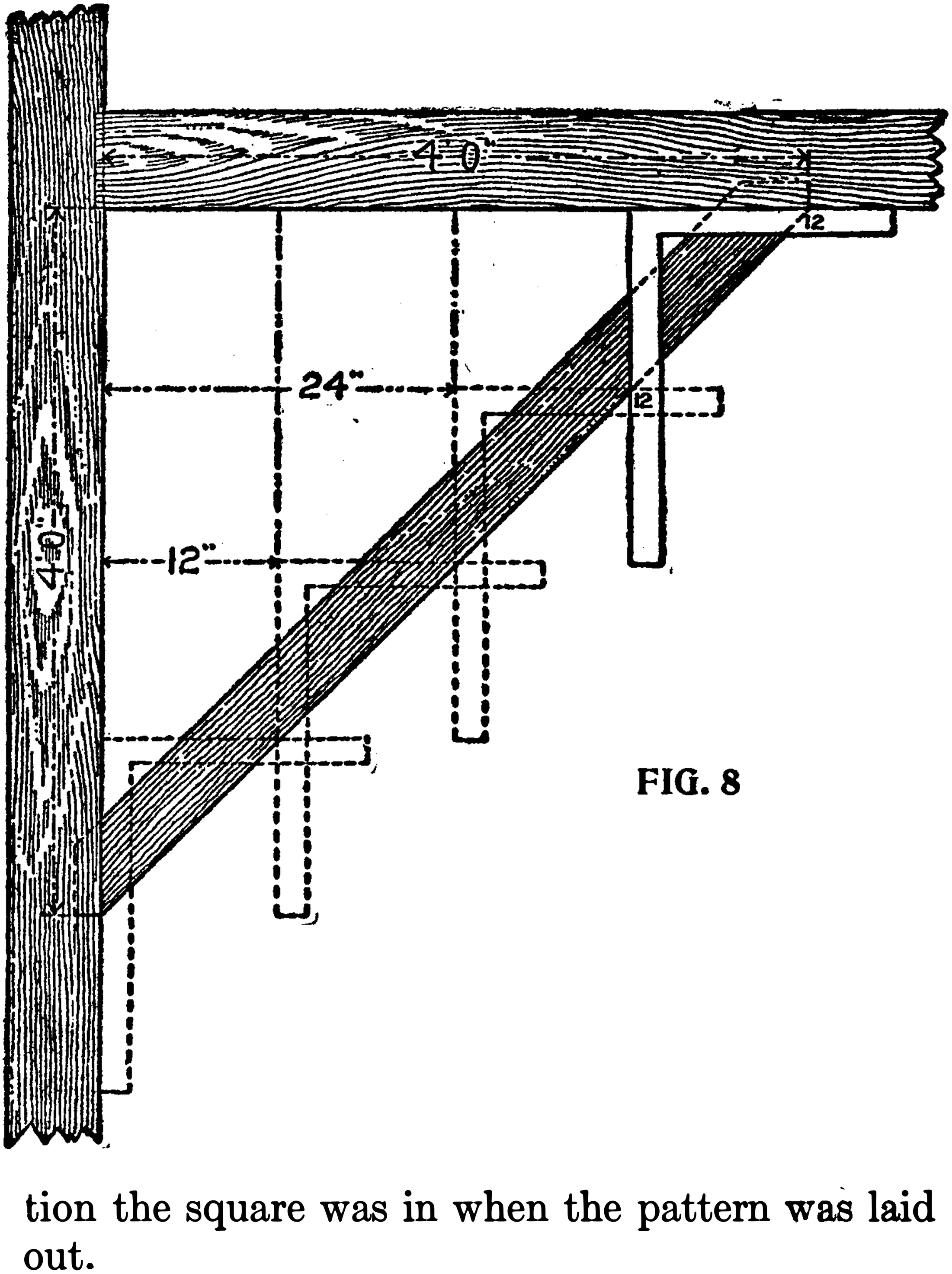

FIG. 8

tion the square was in when the pattern was laid out.

It may be necessary to state that the "square," as now arranged, will lay out a brace pattern

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Fig. 10 shows the brace in position, the dotted lines show where the square was placed on the

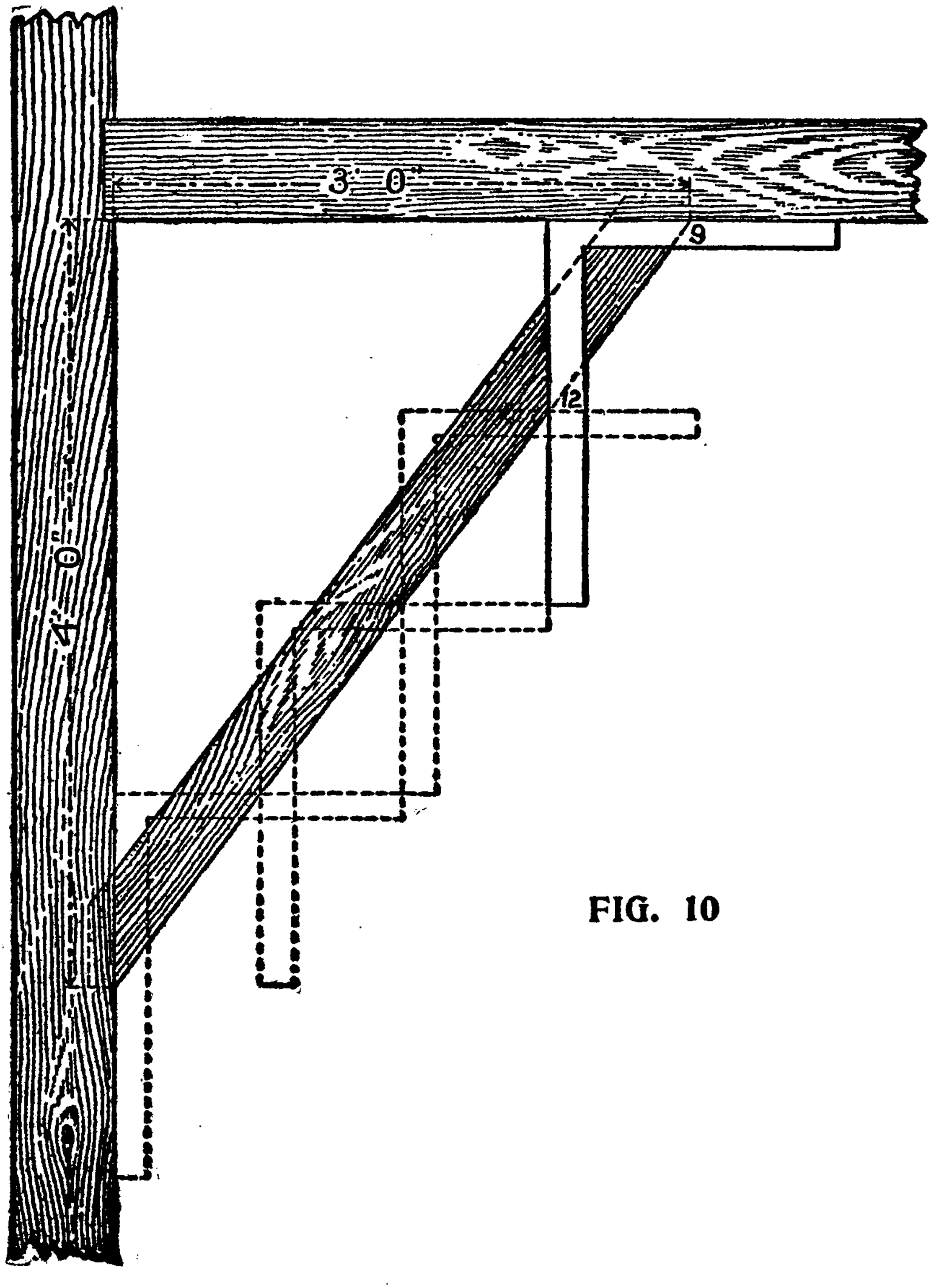


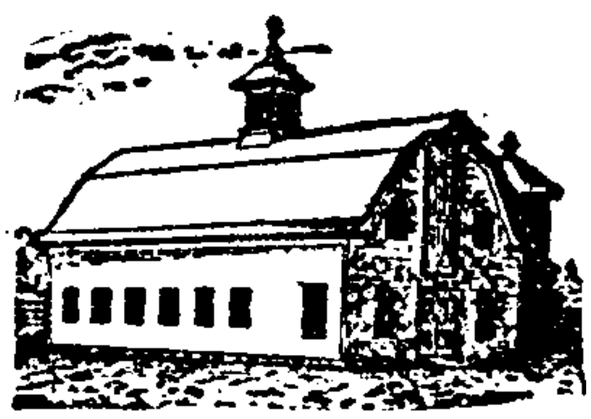
FIG. 10

pattern. It is well to thoroughly understand the method of obtaining the lengths and bevels of

irregular braces. A little study will soon enable any person to make all kinds of braces.

If we want a brace with a two-foot run, and a four-foot run, it must be evident that, as two is the half of four, so on the square take 12 inches on the tongue, and six inches on the blade, apply four times, and we have the length, and the bevels of a brace for this run.

For a three by four-foot run, take 12 inches on the tongue, and 9 inches on the blade, and apply four times, because, as 3 feet is $\frac{3}{4}$ of four feet, so 9 inches is $\frac{3}{4}$ of 12 inches.



Roof Framing

There is probably no part of a building in the construction of which the steel square will be found of greater direct usefulness, than the roof. In the framing of this most important part of the structure—on which the very life of the building, as well as the health and comfort of its inmates, will depend—there arise many problems of greater or less difficulty, which would be very difficult of solution were it not for the steel square.

Rafters.—Fig. 11 shows a plan of a roof having twenty-six feet of span. The span of a roof is the distance over the wall plates measuring from A to A, as shown in Fig. 11. It is also

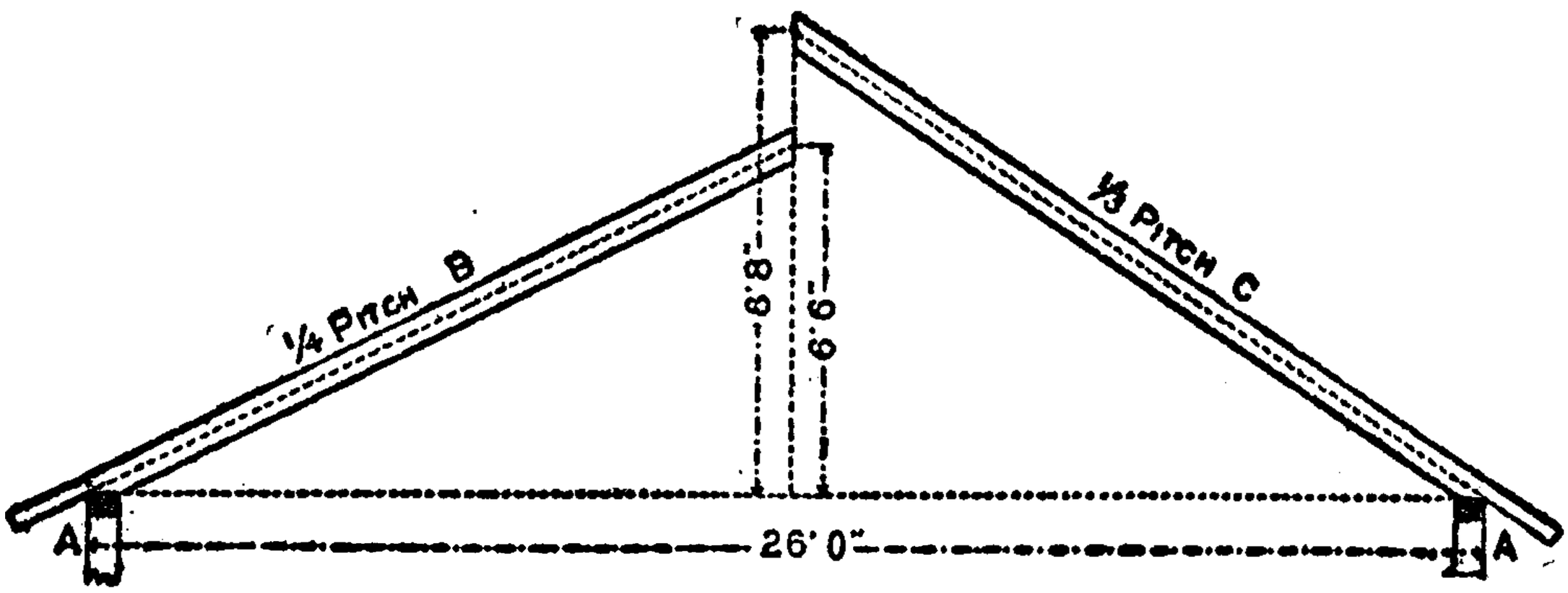


Fig 11.

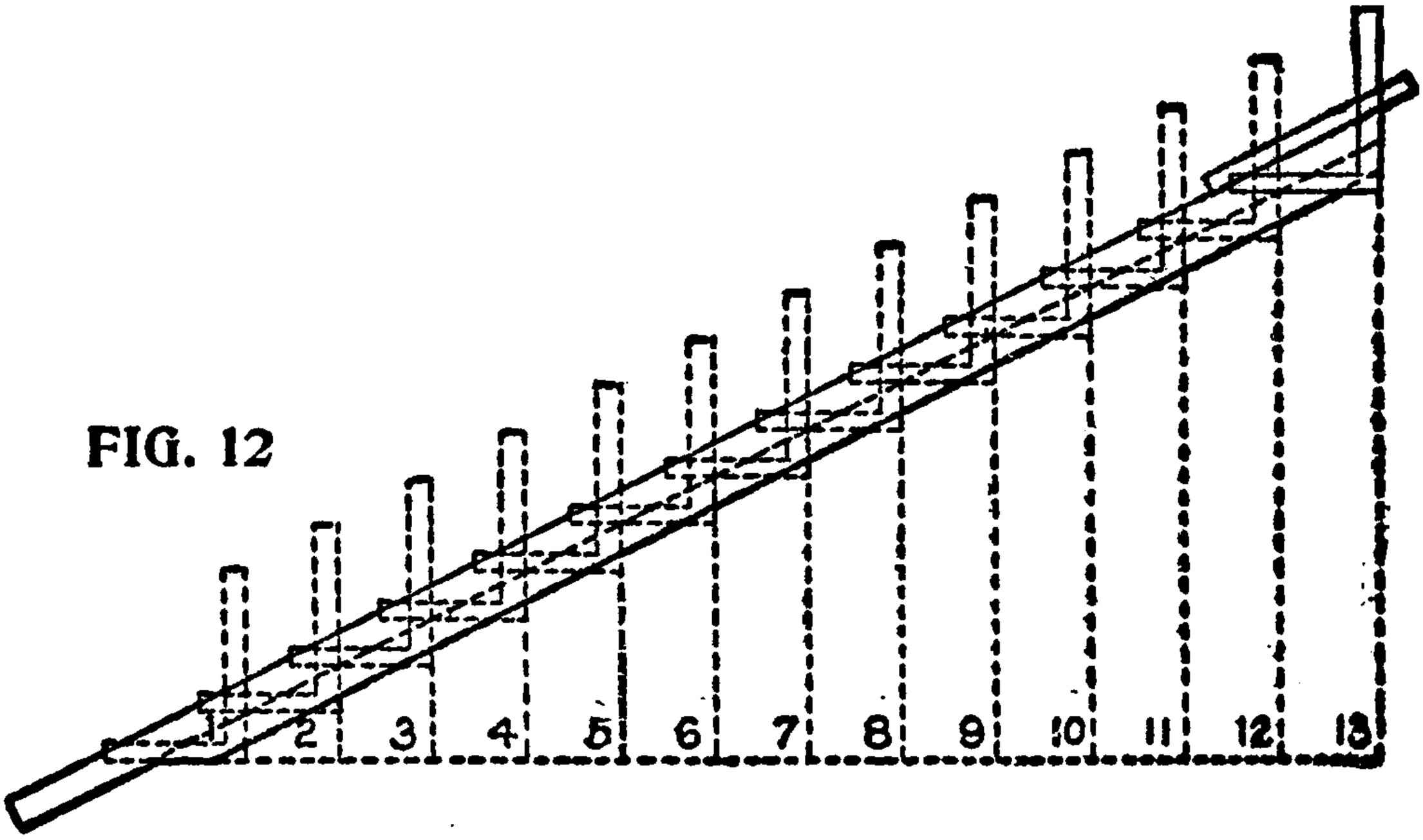
the extent of an arch between its abutments.

There are two rafters shown in position in Fig. 11. The one on the left is at an inclination of quarter pitch, and marked B; and the one on

the right, marked C, has an inclination of one-third pitch. These angles or inclinations rather, are called quarter and third pitch, respectively, because the height from level of wall plates to ridge of roof is one-quarter or one-third the width of building, as the case may be.

In Fig. 12, the rafter B is shown drawn to a larger scale; you will notice that this rafter is for quarter pitch, and for convenience, it is supposed to consist of a piece of stuff 2 inches by 6 inches

FIG. 12



by 17 feet. That portion of the rafter that projects over the wall of the building, and forms the eave, is any width desired. The length of the projecting piece in this case is one foot—it may be more or less to suit the eave, but the line must continue from end to end of the rafter, as shown on the plan, and we will call this line our working line.

Laying out a Rafter.—We are now ready to lay out this rafter, and will proceed as follows:

We adjust the fence on the square the same as for braces, press the fence firmly against the top edge of rafter, and place the figure 12 inches on the left hand side, and the figure 6 inches on the right-hand side, directly over the working line, as shown on the plan. Be very exact about getting the figures on the line, for the quality of the work depends much on this; when you are satisfied that you are right, screw your fence tight to the square. Commence on No. 1 on the left, and mark off on the working line; then slide your square to No. 2, repeating the marking and continue the process until you have measured off thirteen spaces, the same as shown by the dotted lines in the drawing. The last line on the right-hand side will be the plumb cut of the rafter, and the exact length required, which will be found to be 14 feet 6½ inches plus the projection given the eave. It will be noticed that the square has been applied to the timber thirteen times.

The reason for this is, that the building is twenty-six feet wide, the half of which is thirteen feet, the distance that one rafter is expected to reach, so, if the building was thirty feet wide, we should be obliged to apply the square fifteen times instead of thirteen. We may take it for granted, then, that in all cases where this method is employed to obtain the lengths and bevels, or cuts of rafters, we must apply the square half as many times as there are feet in the width of the building being covered. If the building

to be covered is one-third pitch, all to be done is to take 12 inches on one side of the square and 8 inches on the other and operate as for quarter pitch.

We shall frequently meet with roofs much more acute than the ones shown, but it will be easy to see how they can be managed. For instance, where the rafters are at right-angles to each other, apply the square the same as for braces of equal runs, that is to say, keep the 12 mark on the blade, and the 12 mark on the tongue, on the working line. When the roof is more acute, or "steeper" than a right-angle, take a greater figure than twelve on one side of the square, and twelve on the other.

Whenever a drawing of a roof is to be followed, we can soon find out how to employ the square,

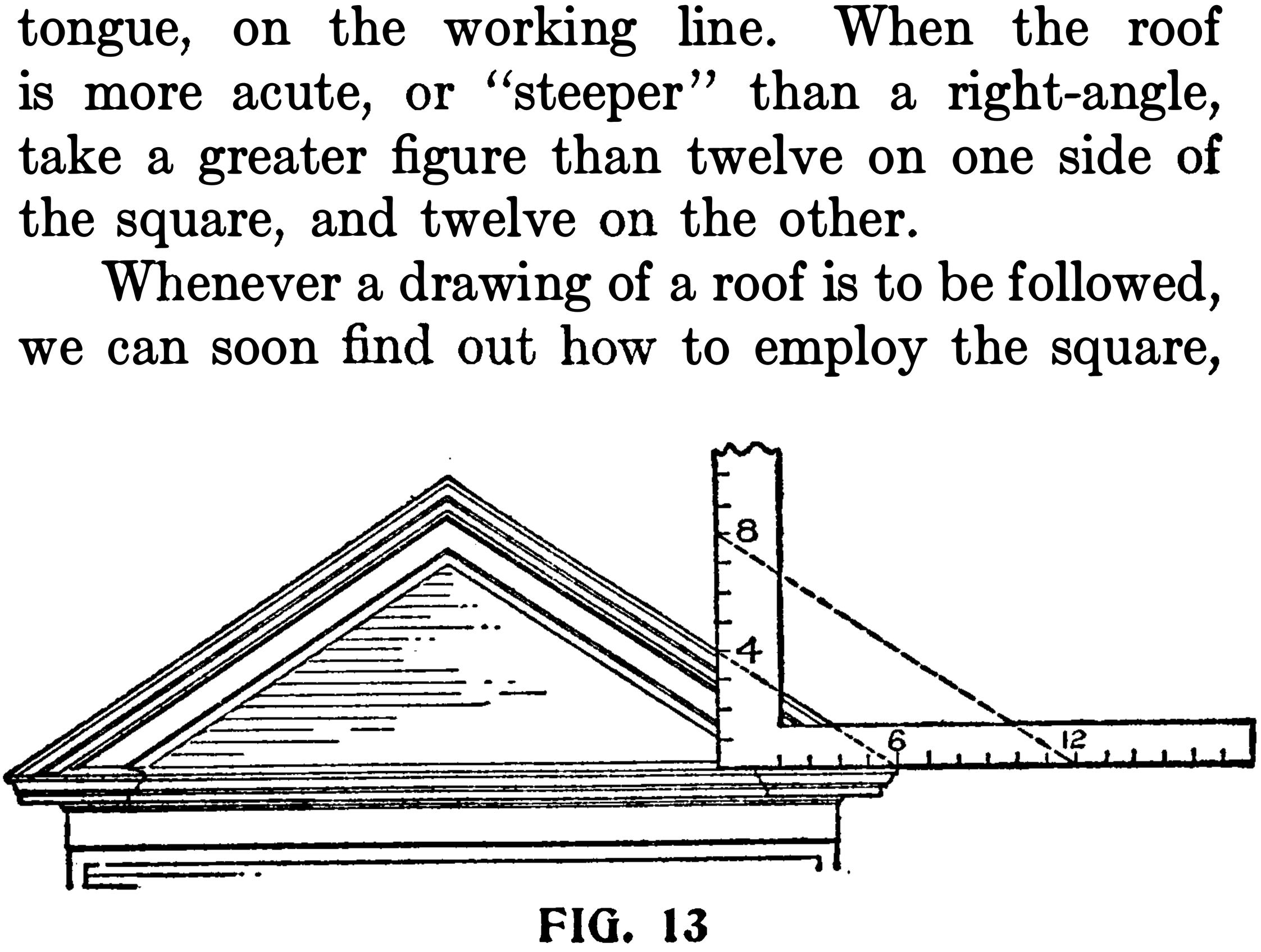


FIG. 13

by laying it on the drawing, as shown in Fig. 13. Of course, something depends on the scale to which the drawing is made. If any of the ordinary fractions of an inch are used, the intelligent workman will have no difficulty in discovering

what figures to make use of to get the "cuts" and lengths desired.

Pitches and Fractions.—Sometimes there may be a fraction of a foot in this division; when such

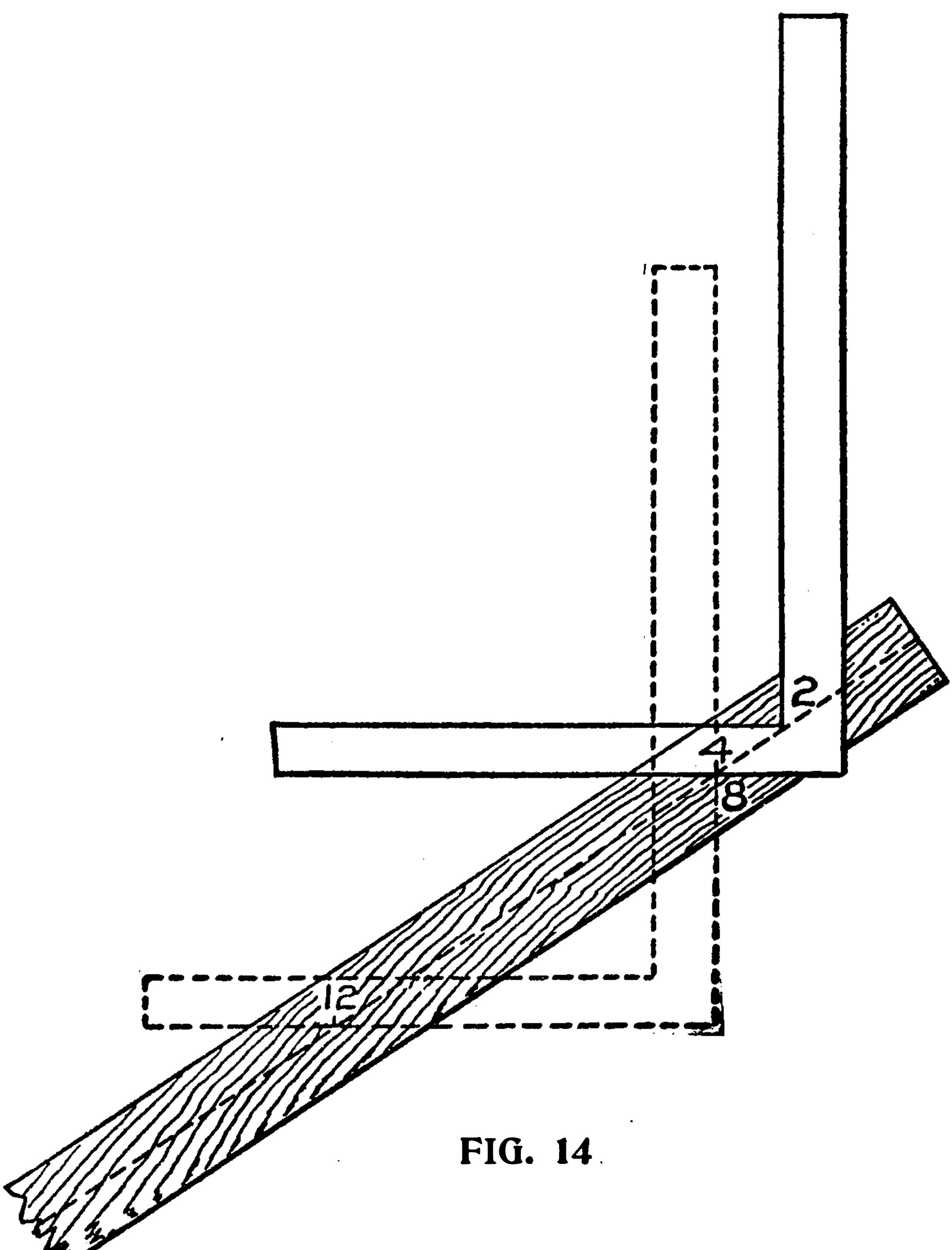


FIG. 14

is the case, it can be dealt with as follows: Suppose there is a fraction of a foot in the span, say 8

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inches, the half of which would be 4 inches, or one-third of a foot; then if the roof is quarter pitch, all to be done is to place the square, with the 4-inch mark on the tongue, and the 2-inch mark on the blade, on the center line of the rafter, and the distance between these points is the extra length required, and the line down the blade

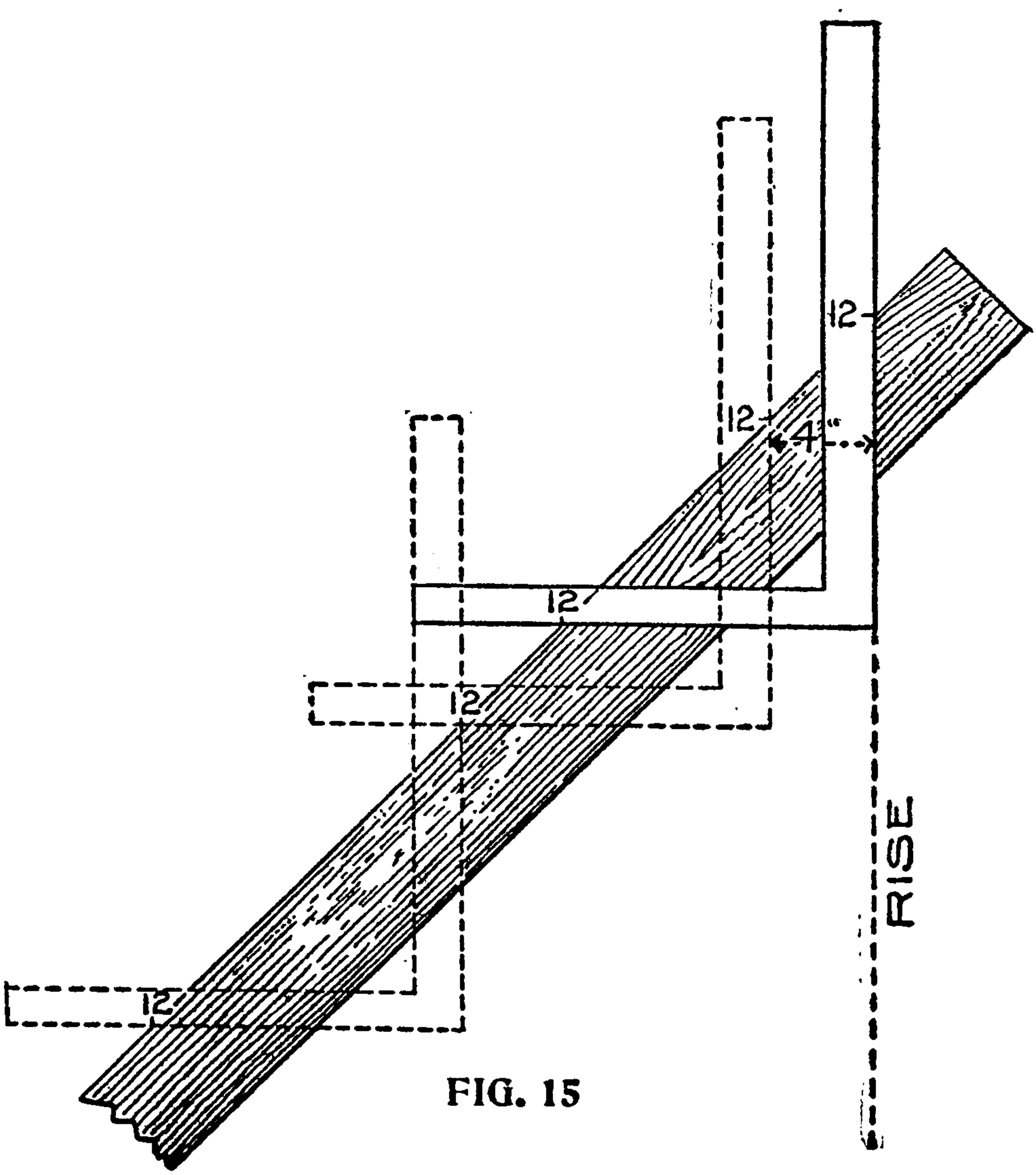

FIG. 15

is the bevel at the point of the rafter. In Fig. 14, is shown an application of this method, or the

correct result may be obtained by measuring at right-angles from the last application of the square as shown in Fig. 15. All other pitches and fractions can be treated in this manner without overtaxing the ingenuity of the workman.

How to Get the Bevels.—Fig. 16 shows how

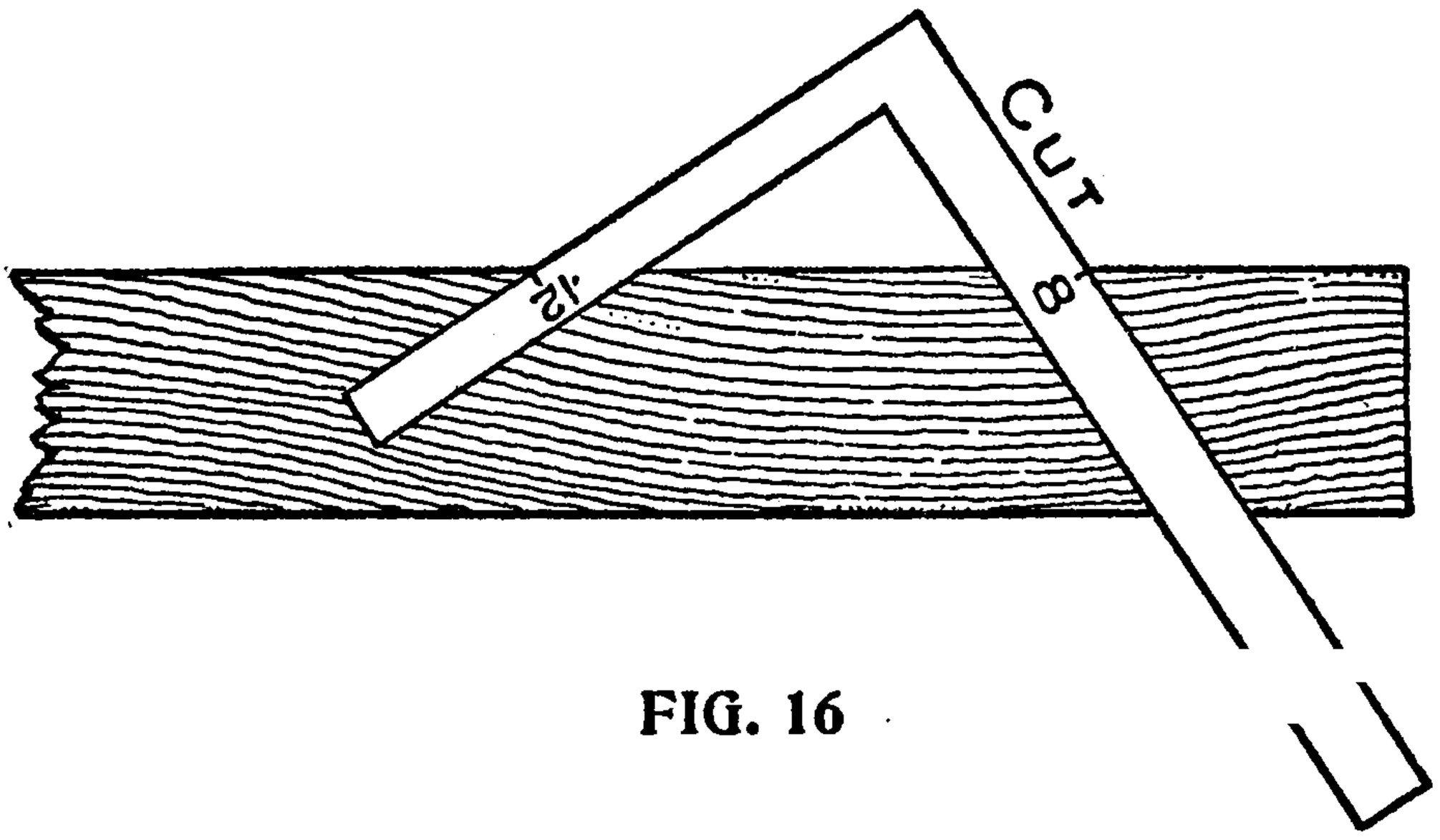

FIG. 16

to get the bevels on the top end of vertical boarding, at the gable ends, suitable for the third pitch at Fig. 11.

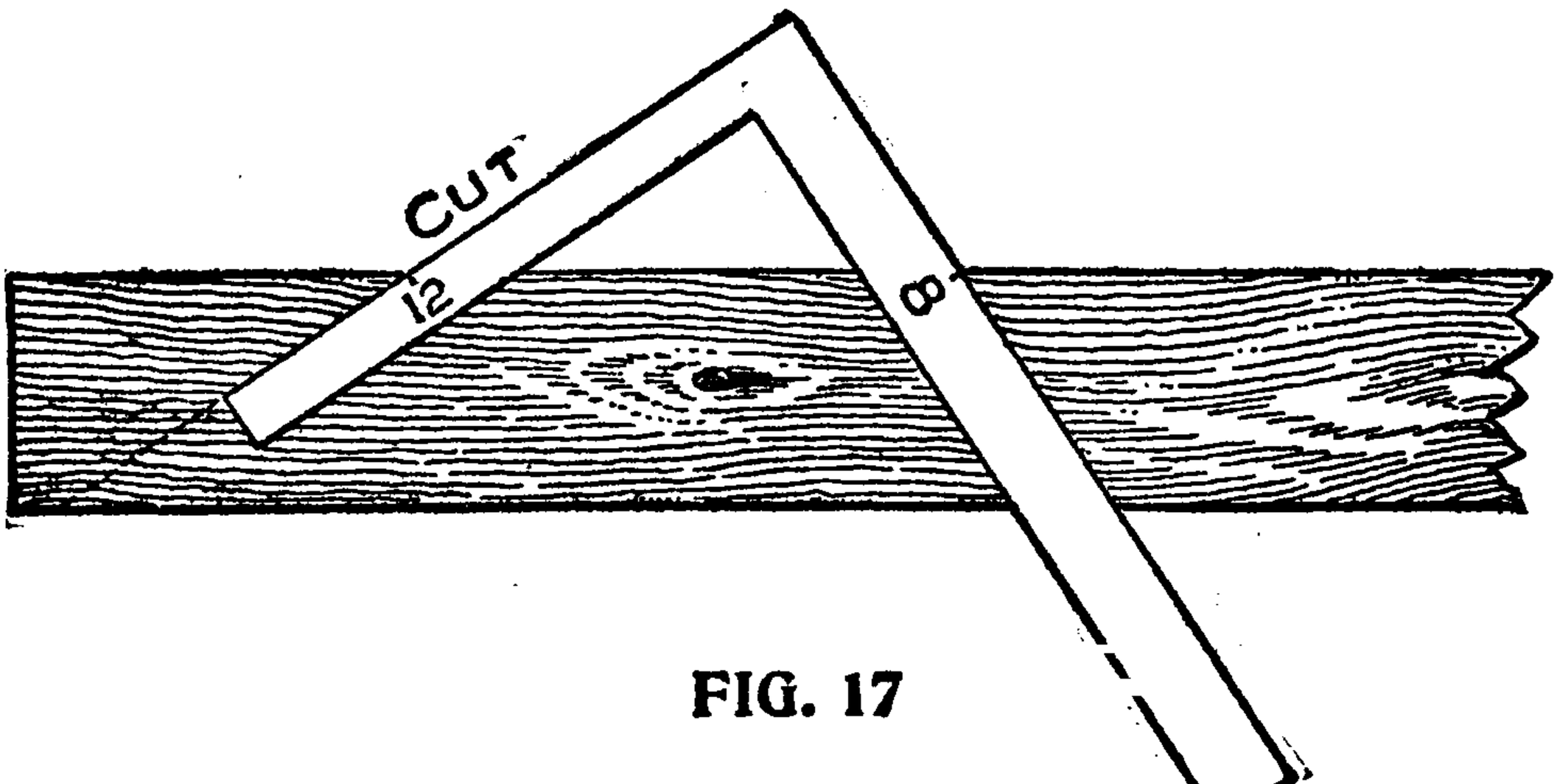

FIG. 17

In Fig. 17 is shown a method for finding the

bevel for horizontal boarding, collar ties, etc. Both of the above are for the one-third pitch.

Roof Pitches Explained.—Inasmuch as roof pitches are not as well understood as they should

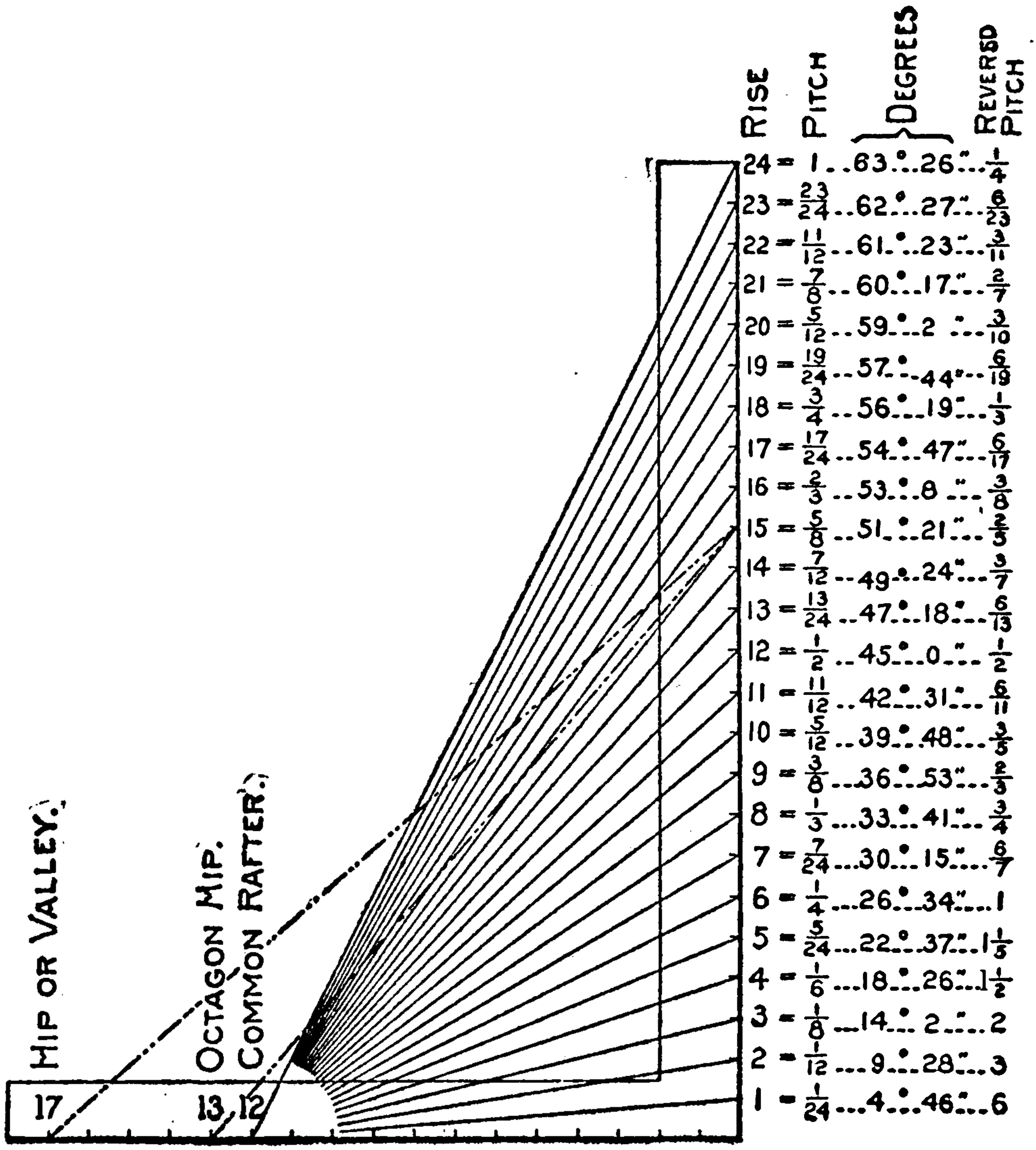

FIG. 18

be, we have thought best at this point to quote from an article, by A. W. Woods, recently published in a trade paper, which will help the student to more fully grasp the subject. In discussing

"pitch" he says: The word "pitch" has reference to the rise given the common rafter in proportion to the span. Therefore by letting 12 on the tongue represent the run of the common rafter the figures on the blade will then represent the rise in proportion to its length (the blade), as 6 being one-fourth of 24 represents the quarter-pitch, 8 represents the one-third pitch, 12 the one-half pitch, etc. See illustration. Fig. 18. For full illustration of roof pitches see Fig. 49A.

For the corresponding hip or valley for the octagon or square cornered building substitute 13 and 17 on the tongue, respectively. However, neither is absolutely correct, but near enough for practical purposes.

The lengths taken diagonally from 12, 13, and 17 on tongue to the figures designating the rise on the blade represent the lengths of the above rafters for a one-foot run. The diagonal lines in the illustration from those figures to 15 on the blade represent five-eighths pitch. Only three of the lengths out of seventy-two are without fractions and they are for the common rafters, as follows: 12 to 5=13 inches, 12 to 9=15 inches and 12 to 16=20 inches. It is on the latter that the rule 6, 8, and 10, so generally used for squaring frame work, is founded. Of course, any of the other angles could be used for this purpose, but the above being without fractions are easy numbers to remember.

The length of the common rafter doubles its run or has a length equal its span when it

has a rise of 60 degrees, which taken on the square is 20.784 inches rise to the foot. The same is true of the octagon hip when it has a rise of a fraction less than 23 inches, and that for the common hip at nearly 29½ inches rise to the foot.

Reversed Pitches.—In the illustration the reversed pitches are also given, that is by letting the blade represent the run and the tongue the rise. The length of the diagonal lines in that case becomes the length of the rafter for a one-foot rise to the inches in run taken on the blade.

The reader will notice that several of these pitches are transposed and are found in the first column, as follows: The 1 pitch is the same as the $\frac{1}{4}$ pitch when reversed. The $\frac{3}{4}$ same as $\frac{1}{3}$; the $\frac{2}{3}$ same as $\frac{3}{8}$; the $\frac{1}{2}$ remains the same or unchanged. The low pitches in the first column become very steep when reversed; thus, the $\frac{1}{24}$ pitch becomes 6 pitches or a rise of 12 feet to a one-foot run. The $\frac{1}{12}$ pitch is equal to a rise of 6 feet to a 1-foot run, etc.

For the corresponding lengths of the hip or valley for the reversed pitches add one-twelfth and five-twelfths to the run of the common rafter for the octagon and right-angled corner respectively. In our illustration we also give the degree of pitch for common rafter. To find the same for reversed pitches, it is only necessary to subtract the degrees here given from 90 degrees.

In the following Mr. Woods gives explanations and diagrams for finding the lengths of rafters where the rises in the roof are of different heights.

Irregular, Uneven, or Unequal Pitches, are simply different pitches in the same roof. When they are the same on all sides and the building is square, the hips or valleys run in from the corners at an angle of 45 degrees, regardless of the rise of the roof; but should one side be steeper than the adjoining side, or the gables be of different pitch from the main roof, then the hips or valleys depart from the 45-degree angle.

Fig. 19 shows a roof plan with the one-third

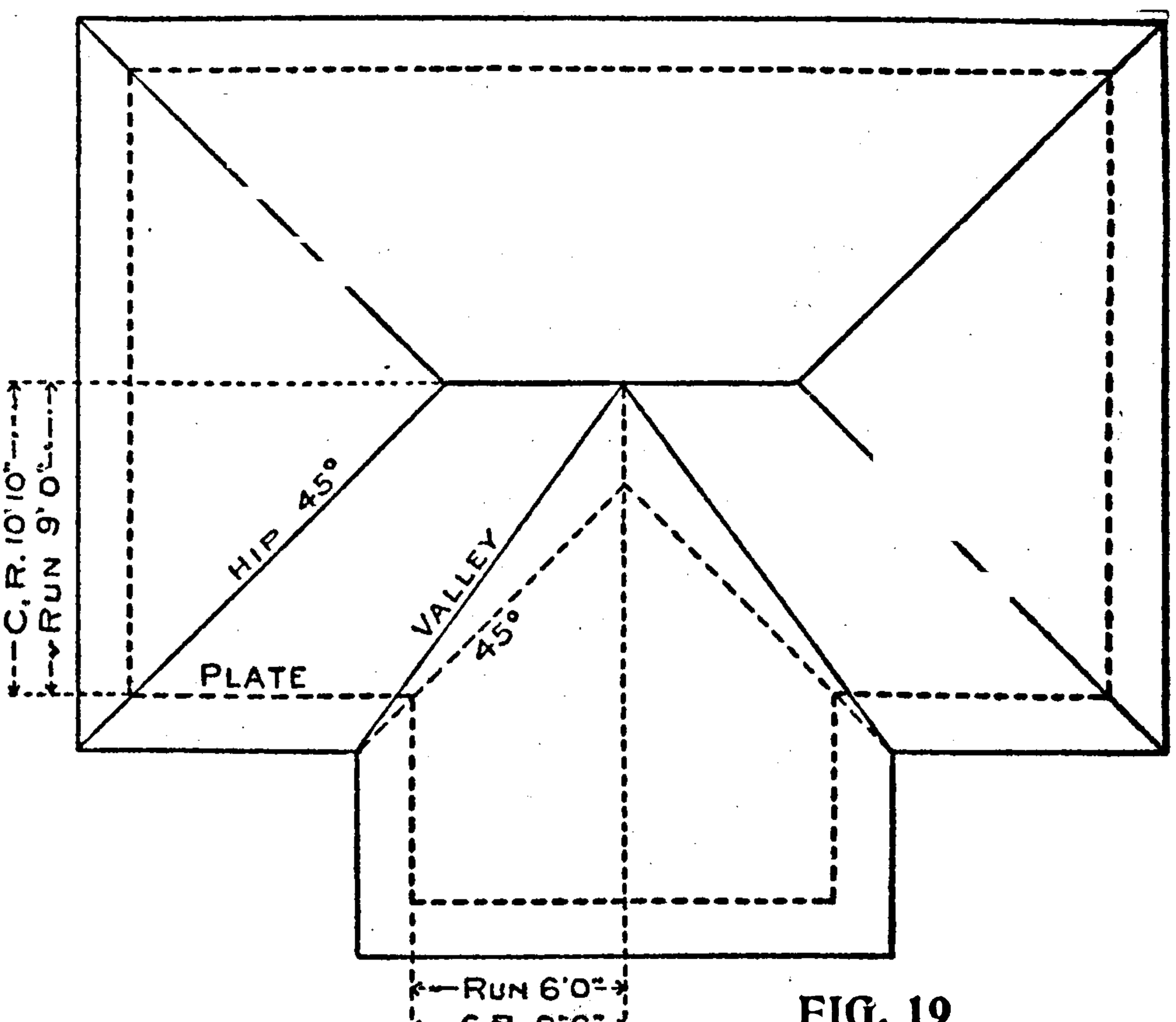

FIG. 19

pitch on the main part, with a half-pitch gable. The seat and down cuts of the jack and common

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for the right jack. Figs. 20 and 21 illustrate these cuts.

Projecting Cornice.—Here is another problem that comes in connection with the uneven pitched roof. Where a projecting cornice is desired, with planceer, the valley will not rest on the angle of the plate, but at a point in line with the intersection of the cornice.

This necessitates the plate on the steeper

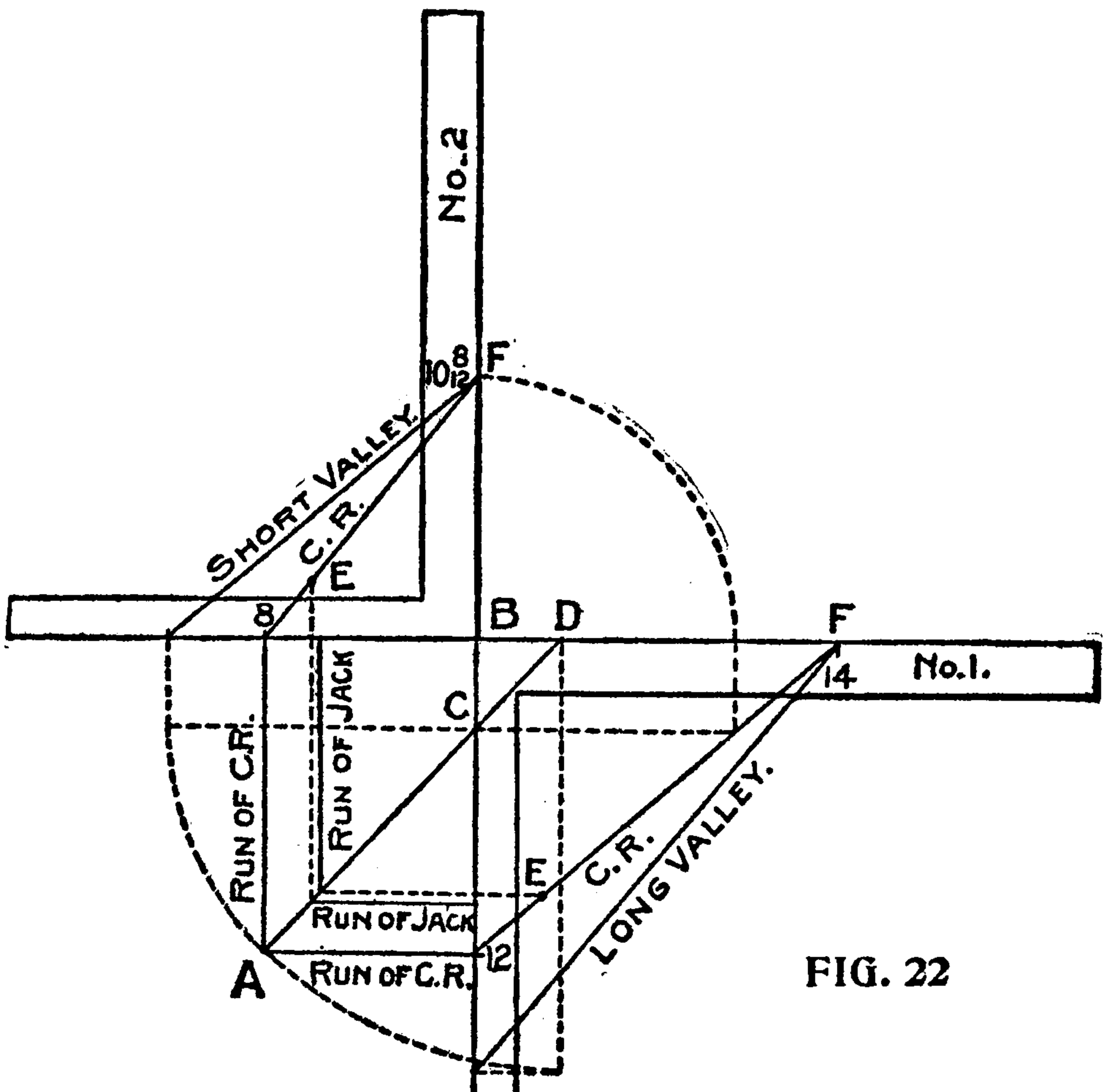

FIG. 22

pitch being raised as much as the difference in the rise of the pitches; in the width of the cornice.

Thus, if the cornice be 18 inches wide, the rise of the half pitch is 18 inches, and that of the one-third pitch is 12 inches, a difference of six inches. Therefore the proper height of the plate above that of the lower pitch is six inches.

To Find the Length of Rafters Where the Rises in the Roof are of Different Height; for example, we will suppose the main gable, Fig. 22, to be 24 feet wide with a 14-foot rise, and the side gable to be 16 feet wide with a 10-foot 8-inch rise. In a case of this kind it is better to let one of the valleys extend on up to the ridge board of the main gable and let the other valley rest against it (the long valley). But how to locate them on the square is the main question. 1st. Place the squares as shown. On square No. 1 lay off the run and rise of the wide gables, and the same for the narrow gable on square No. 2.

2d. By connecting the run and the rise, as shown by the diagonal line on each of the squares will be the length of the common rafter.

3d. Square out from the tongue as shown, till they intersect at A, which will be the runs of the gables or of the common rafters.

4th. Set compasses at B, and open to equal the rise of the narrow gable and swing to the blade of No. 1, and square in to the common rafter, thence run an imaginary line parallel to the blade, and where it intersects the tongue establishes the point where the ridge of the narrow gable or dies intersects on main roof and which point we will call C.

5th. A line drawn from A to C represents the run of the short valley and by extending the line on to the blade of No. 1 establishes point D, from which to B, represents the run of the long valley, and these lengths taken on the tongues as shown, and connected with their respective rises, will be their lengths.

6th. The lengths of the jacks are found as shown from E to F, which we trust is clear enough without further explanation.

The cuts and bevels are all contained in this diagram.

The Pitch of the Tower Roof may be obtained along with all the bevel lines by the proper use of the steel square, as shown in Fig. 23, which illustrates some unusual pitches. It is evident that if the run of 1 foot is 12 inches, the span must be double that or 24 inches; therefore the rise must be that proportion of the

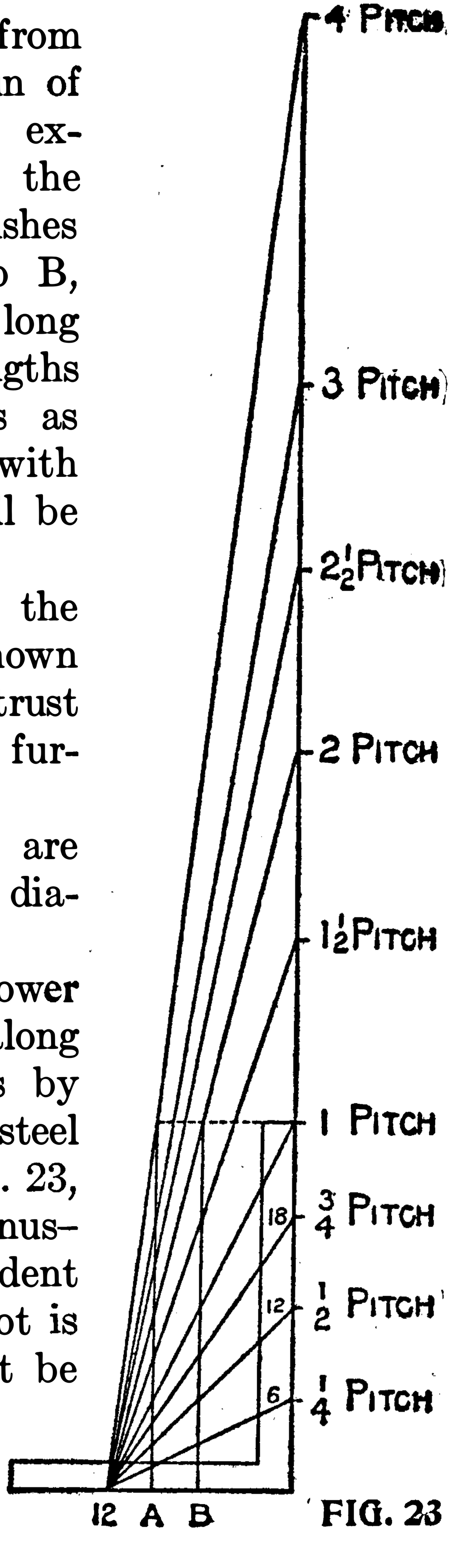

FIG. 23

span. Then the first inch in rise is one-twenty-fourth, the second one-twelfth, the third one-eighth, etc. The twenty-fourth inch rise being equal the span, it is therefore one pitch. As the rise continues above this point, it is simply a repetition of the above with a 1 prefixed, thus: The twenty-fifth inch rise being one and one-twenty-fourth pitch, etc.; but we are now beyond the limits of the full scale as applied to the square, so we must reduce the scale. By letting the vertical line B represent the blade we will have reduced the scale one-half. The pitches would center at 6 on the tongue instead of 12, as in the full scale. We must now use the half inches above 12 on the blade for each rise of one inch till we reach the twenty-fourth inch, which will be equal to two pitches or 48-inch rise to the foot. For steeper pitches it is necessary to again change the scale. If we let the blade rest at A the pitches will center at 3 on the tongue (making the scale $\frac{1}{4}$ size), and by letting the $\frac{1}{4}$ inches above 12 on the blade represent the full inches in rise will give the cuts, etc., from the forty-eighth inch rise to the ninety-sixth inch rise to the foot, or 4 pitches.

Hip Rafters.—Fig. 24, represents the plan of a roof as furnished by an architect. Fig. 25 shows the square set to the pitch of the common rafter, while Fig. 26 shows the same for the hip rafter. The squares as set give plumb and level cuts. Fig. 24 is the rafter plan of the house 18 by 24 feet; the rafters are laid off on the level, and

measure nine feet from center of ridge to outside of wall; there should be a rafter pattern with a plumb cut at one end, and a foot cut at the other,

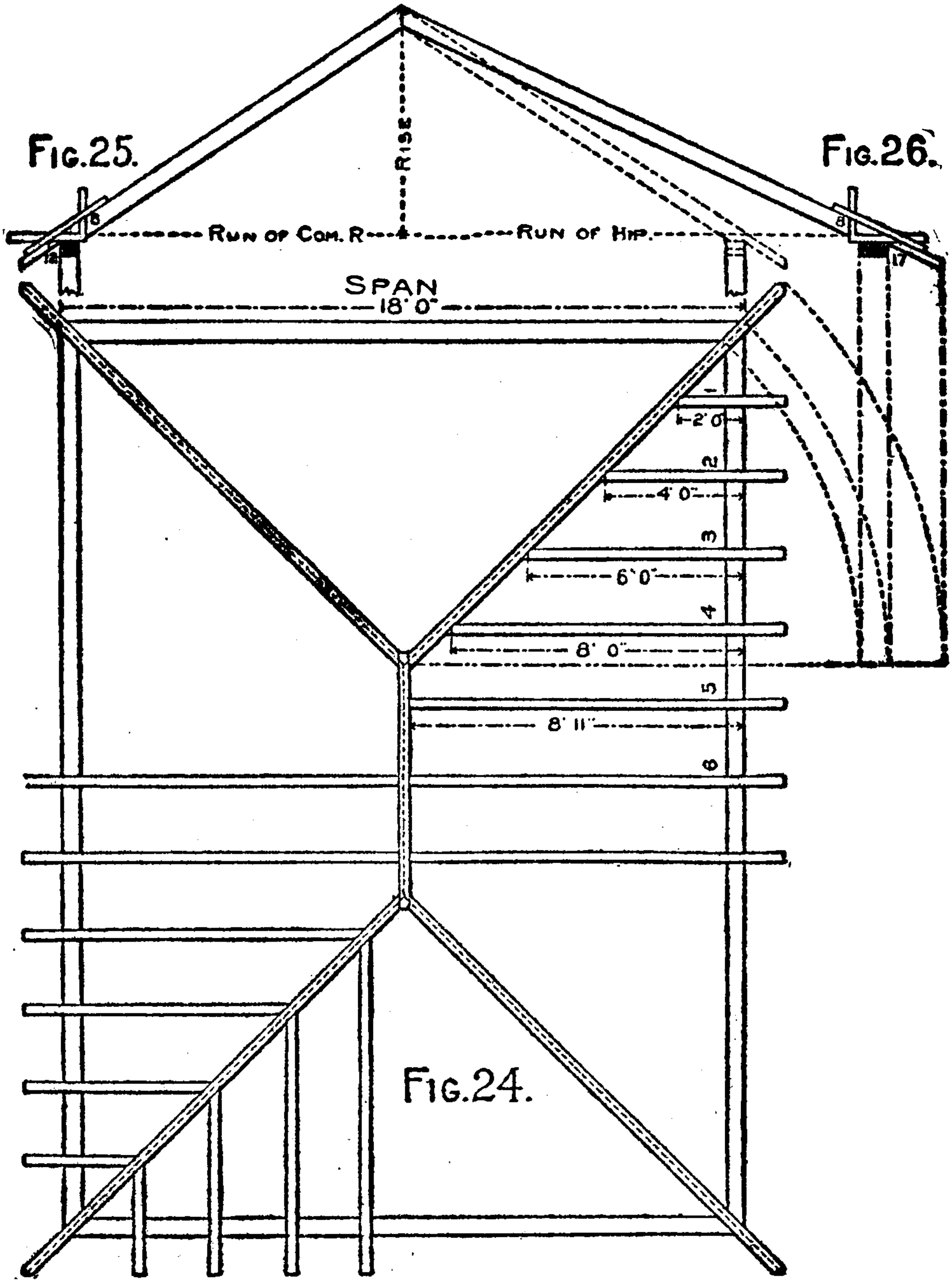

Fig.25. Fig.26.

Fig.24.

gotten out as previously shown. (Fig. 25, 26). When the rafter foot is marked, place 12 on the

long blade of the square to the wall line, as in Fig. 25, and mark across the rafter at the outside of the short blade, and slide the square up the rafter and place the 12 of the long blade to the mark last made and mark outside the short blade as before, repeat the application until nine feet are measured off, and then the length of the rafter is correct; remember to mark off one-half the thickness of ridge-piece, which is done by measuring at right-angles back from the plumb cut. The rafters are laid off on part of plan to show the appearance of the rafters in a roof of this kind, but for working purposes the rafters 1, 2, 3, 4, 5, and 6, with one hip rafter, are all that are required.

Length of Hip Rafters—How to Get the Inches and Fractions.—Fig. 26A shows how to get the length of a hip rafter for a half pitch roof for a building 17 feet 7 inches wide, making 8 feet 9½ inches in the run. For the 8 feet in the run 17 and 12 are taken eight times on the square. The reason 17 is used is because it is the practical length of the diagonal of a one-foot square, and 12 is used because it represents the half pitch to a one-foot run, as shown in Fig. 26A. Therefore these figures taken on the steel square eight times will give the length for the eight feet in the run, and for the nine and one-half inches proceed in the same way taking the diagonal of nine and one-half inches, which is thirteen and one-half, and a line drawn from 13½ parallel with the one from 17 to 12, and the point of intersection on the blade

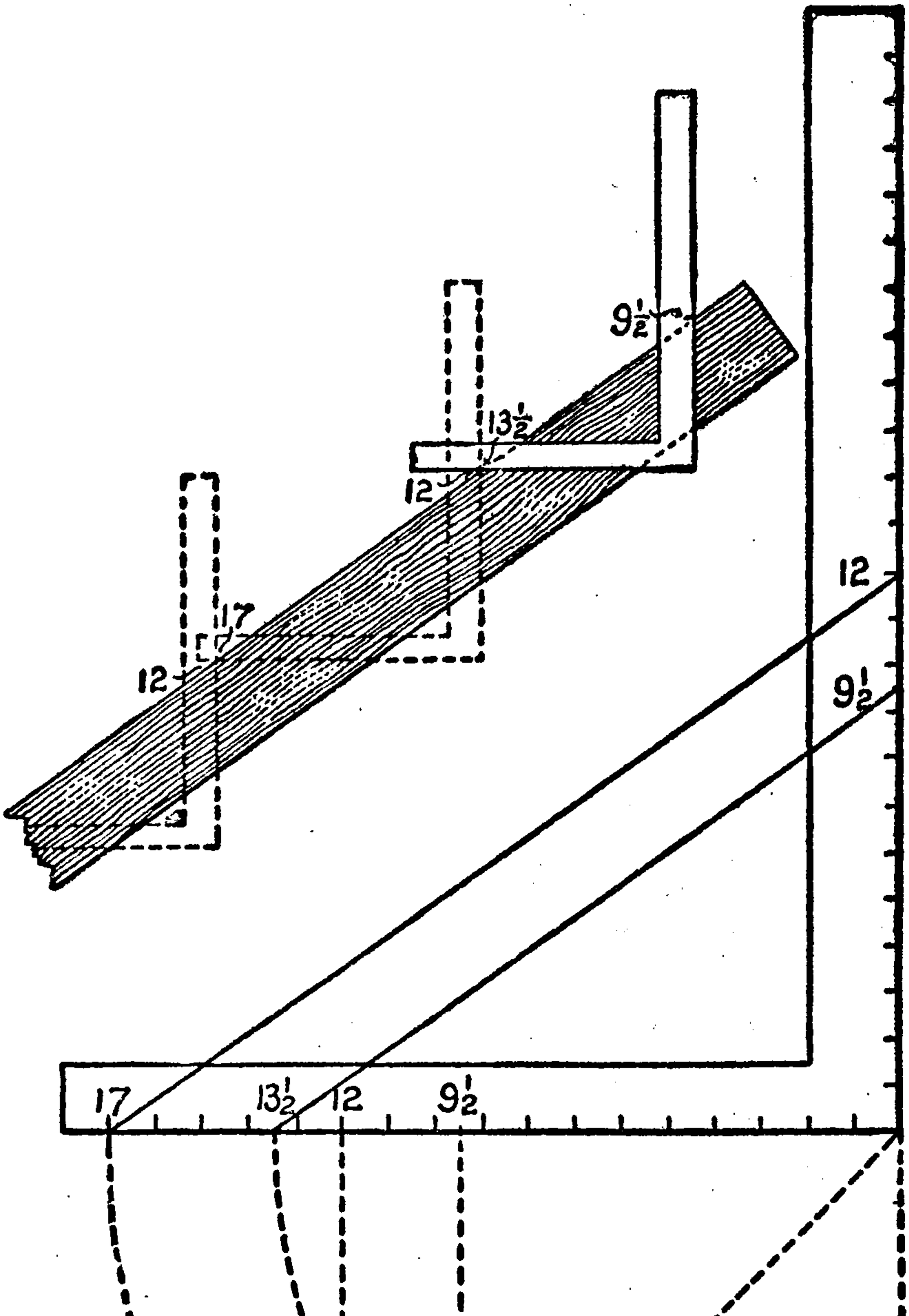

FIG. 26-A

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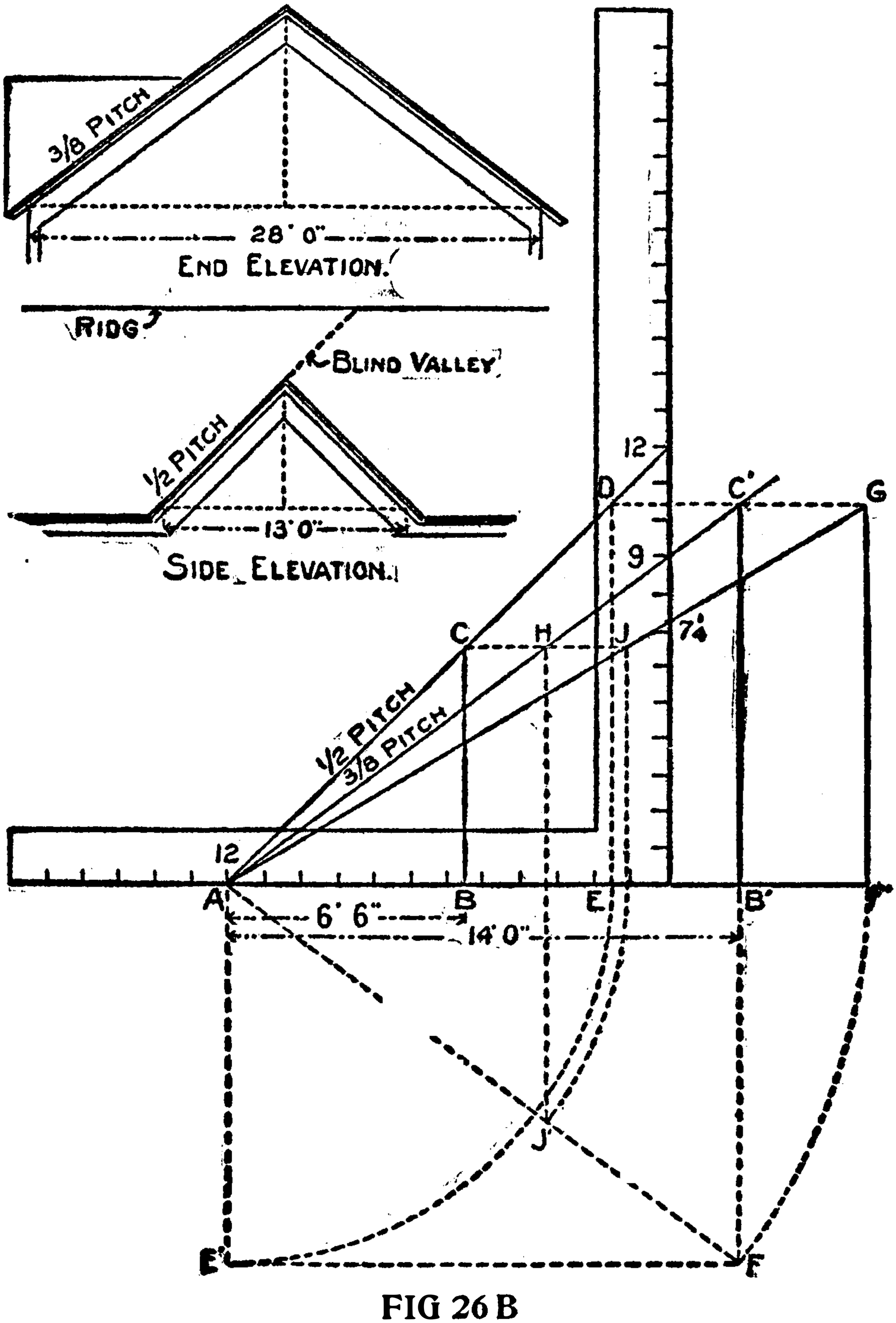

FIG 26 B

that part of the long valley commonly called blind valley. Where the roofs of different pitches

are of the same height it is quite an easy matter to arrive at the length of the valley, as their runs

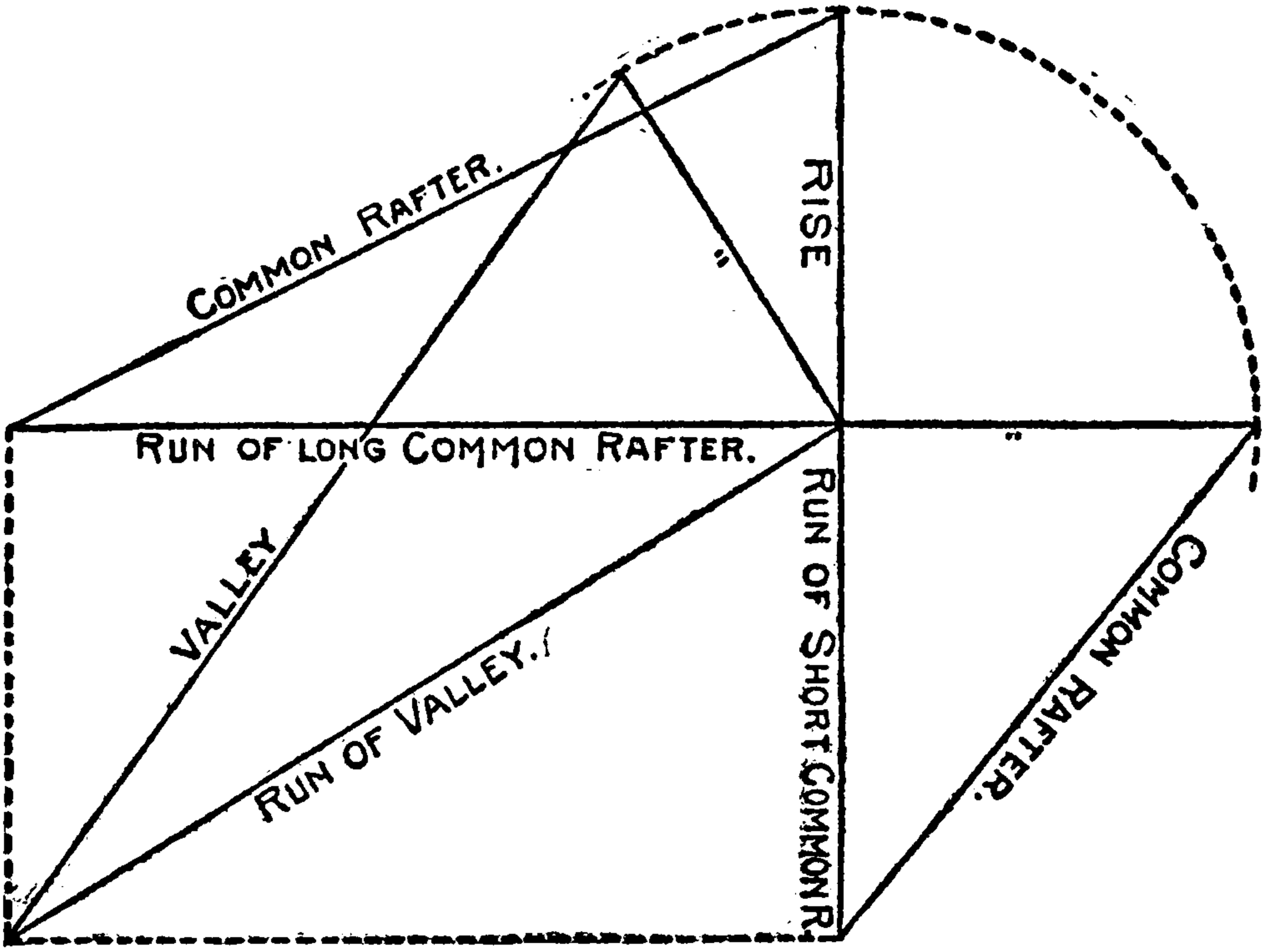

FIG. 26 C

form the sides of the plan as shown in Fig. 26C, which needs no further explanation.

Curved Hip Rafters.—Fig. 27 shows how a curved hip-rafter may be obtained. The rafter shown in this instance is ogee in shape, but it makes no difference what shape the common rafter may be, the proper shape and length of hip may be obtained by this method. It will be noticed that one side of the example shown is wider than the other; this is to show that the rule will work correctly where the sides are unequal in width, as well as where they are equal.

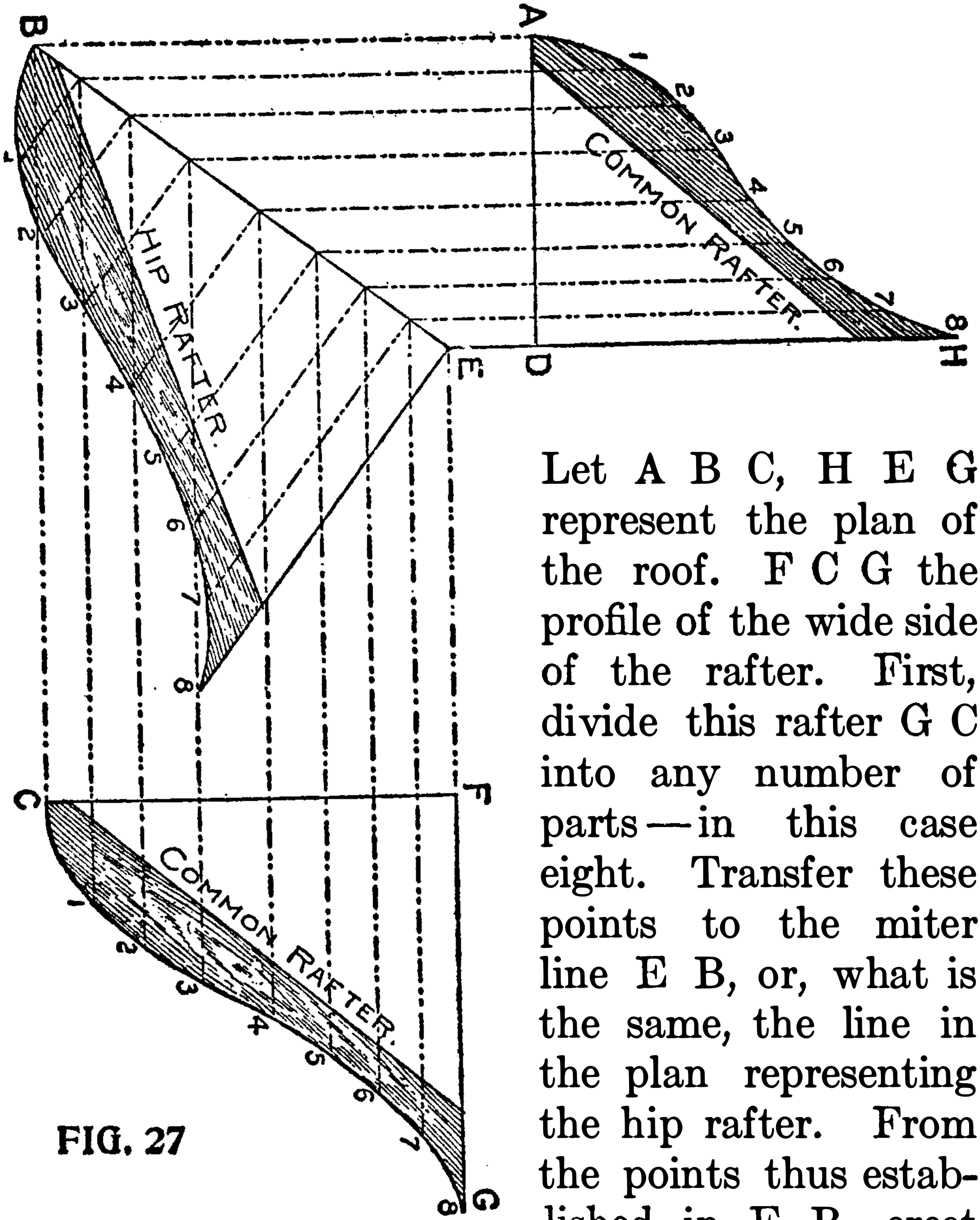

FIG. 27

Let A B C, H E G represent the plan of the roof. F C G the profile of the wide side of the rafter. First, divide this rafter G C into any number of parts—in this case eight. Transfer these points to the miter line E B, or, what is the same, the line in the plan representing the hip rafter. From the points thus established in E B, erect perpendiculars indefinitely. With the dividers take the distance from the points in the line F C, measuring to the points in the profile G C, and set the same off on corresponding lines, measuring from E B, thus establishing the points 1, 2, 3, etc.; then a line traced through these points will be the required hip rafter.

Common Rafters.—For the common rafter on the narrow side, continue the lines from E B parallel with the lines of the plan H E and A B. Draw A D at right angles to these lines. With the dividers as before, measuring from F C to the points in G C, set off corresponding distances from A D, thus establishing the points shown between A and H. A line traced through the points thus obtained will be the line of the rafter on the narrow side. This is supposed to be the return roof of a veranda, but is only shown as an example, for it is not customary to build verandas nowadays with an ogee roof, but with a rafter having a depression or cove in it. For accuracy it would be as well to make nearly twice the number of divisions shown from 1 to 8, as are there represented.

In speaking further of roof-framing and particularly of framing of hip and valley roofs, Mr. Woods says: Much has been said and can be said on the subject, but it is my aim to say as little and do as much as I can to make the subject clear. Every carpenter knows that the run and rise of the rafter taken on the square will give the seat and plumb cuts, but inasmuch as buildings are not all of the same width, it requires a different set of figures for each run, and as it requires an extra calculation to find the run of the hip or valley, it is better to use the full scale for a one-foot run of the common rafter, which answers for any run.

To Find the Length and Cut of Rafters.—Referring to Fig. 28, we show a square bounded by

A, B, C, D, the sides of which are 12 inches. E is at a point 5 inches from B, and C 12 inches

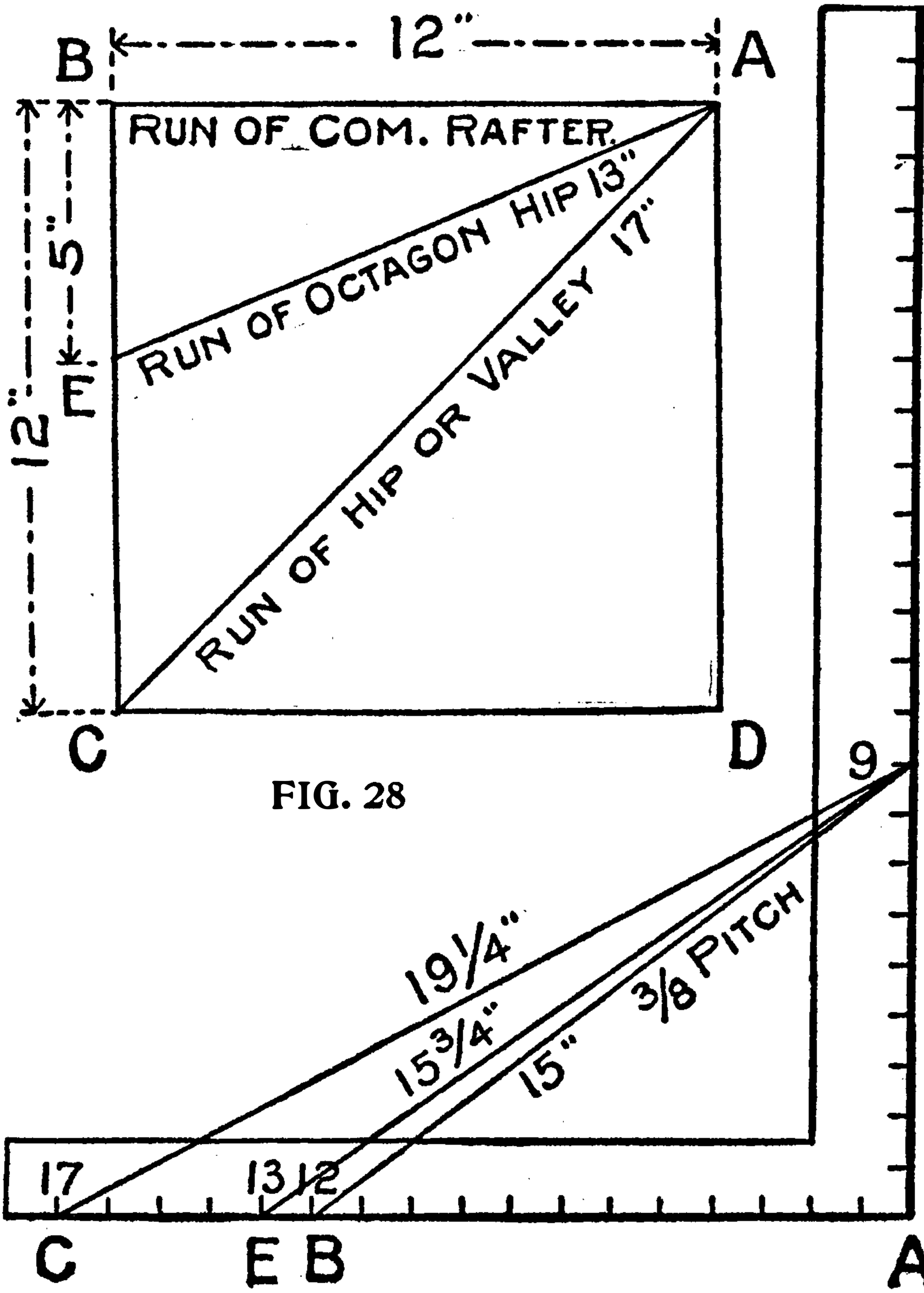

FIG. 28

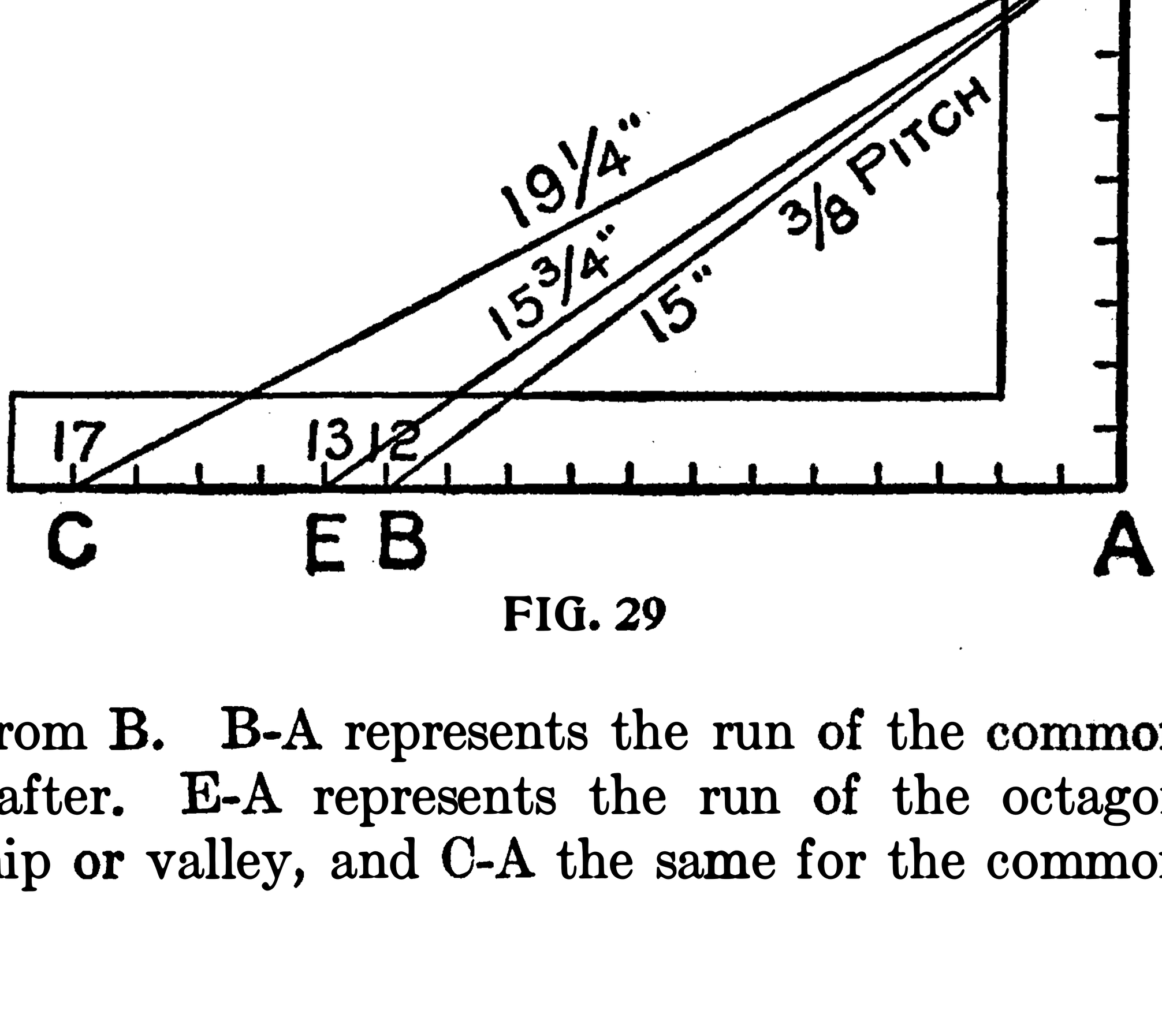

FIG. 29

from B. B-A represents the run of the common rafter. E-A represents the run of the octagon hip or valley, and C-A the same for the common

hip or valley, their lengths being 12, 13, and 17 respectively. Now since 12, 13, and 17 are fixed

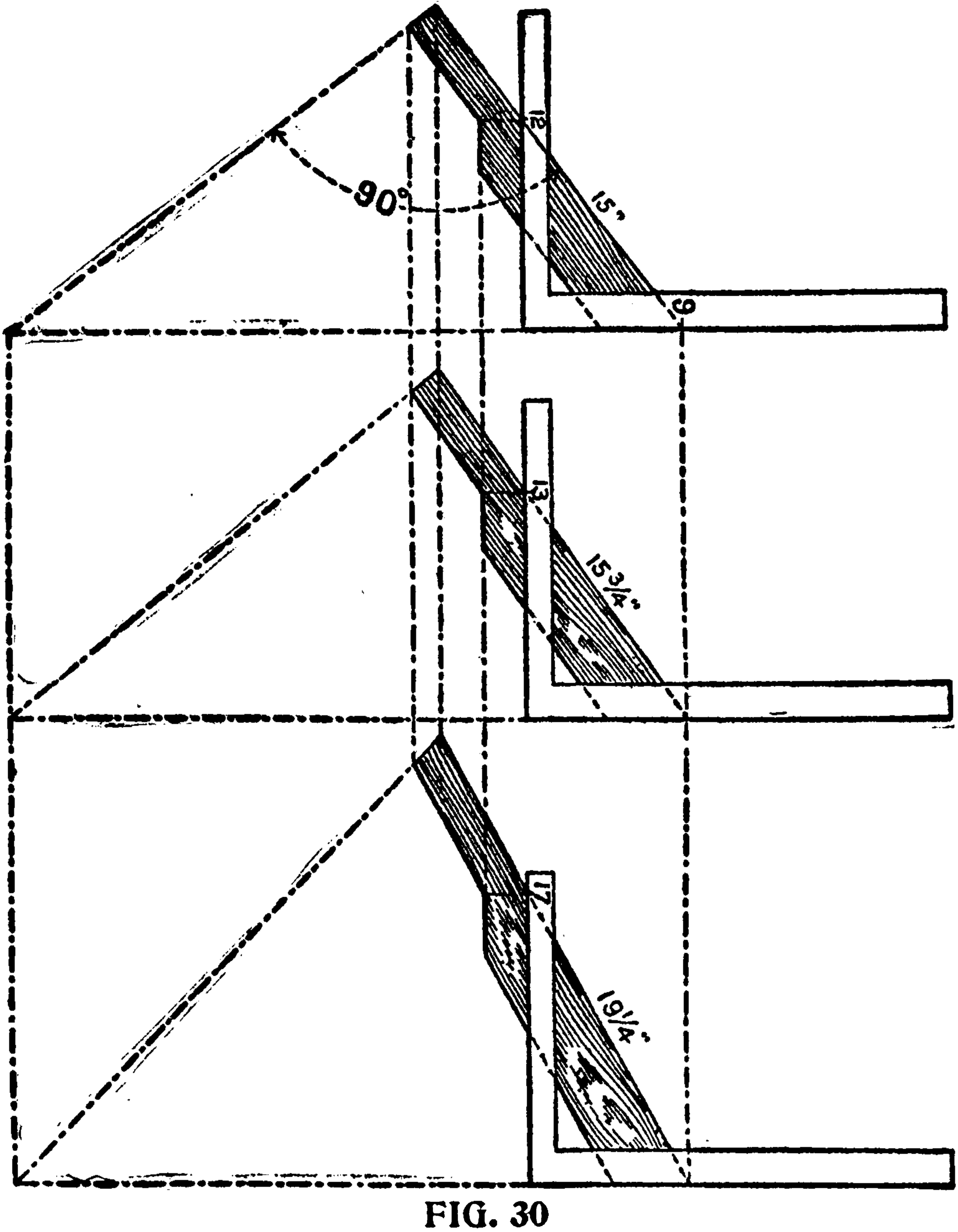

FIG. 30

numbers, we take them on the tongue of the square, as shown in Fig. 29. Now suppose we want to find the lengths and cuts of the rafters

for the ⅜ pitch. We take 9 on the blade. Why? Because the run being 12 inches, the span must be two times 12, which equals 24, and since the pitch is reckoned by the span, we find that ⅜ of 24 is 9, which represents the rise to the foot run.

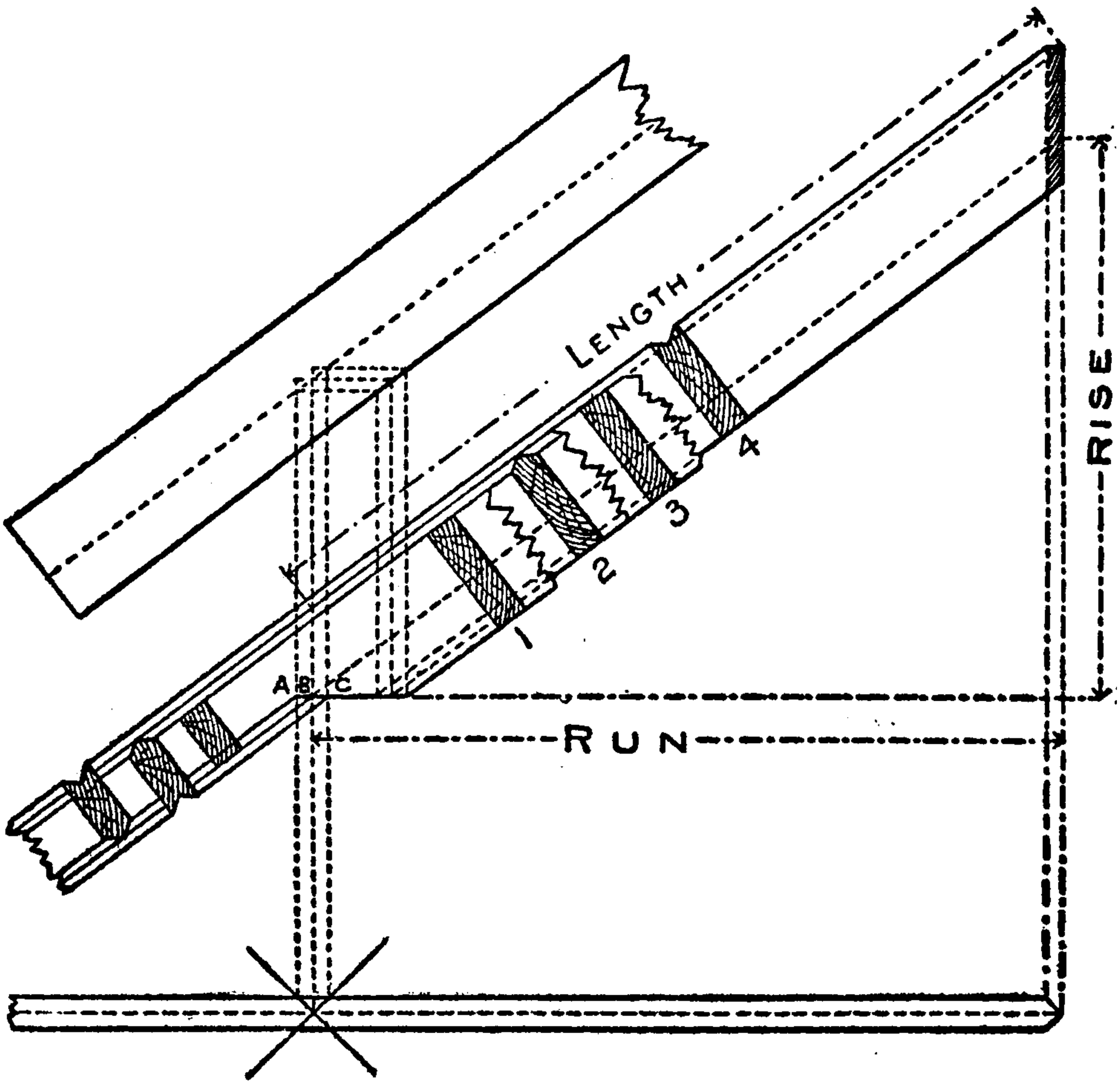

FIG. 31

Then 12 and 9 give the seat and plumb cuts for the common rafter, 13 and 9 for the octagon hip or valley, and 17 and 9 give the same for the common hip or valley. In Fig. 30 we show each separately.

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the latter, but as much lower than No. 3 as No. 2 is below No. 1.

The outer vertical lines from the plan represent the width of the rafter. Therefore if the rafter be two inches thick, would be one inch apart, and this amount set off along the seat line (or a line parallel with it) will give the gauge point on the side of the rafter. To make this clearer refer to Fig. 30; 17 and 9 gives the cuts. Now leaving the square rest as it is, measure back from 17 one-half the thickness of the rafter, and this will be the gauge line point from which to remove the wood back to the center line of hip, and the measurement from the edge of the rafter taken vertically down to the gauge point set off on the plumb cut regulates how far apart the parallel lines of the seat cuts will be under the above conditions. This rule applies to any roof so long as the pitches are regular.

Proceed in like manner for the octagon hip, the variation, however, is five-twelfths or practically one-half of the above results for the square cornered building.

In Fig. 32 is shown the plan of a hip and common rafter in place, also an elevation of same with the hip swung parallel to the common rafter, A C and A B being their respective lengths. This figure also illustrates the relative pitch of one to the other but when set in their respective places on the building are of the same plane.

Fig. 33 illustrates side cut of the jack, 12 on

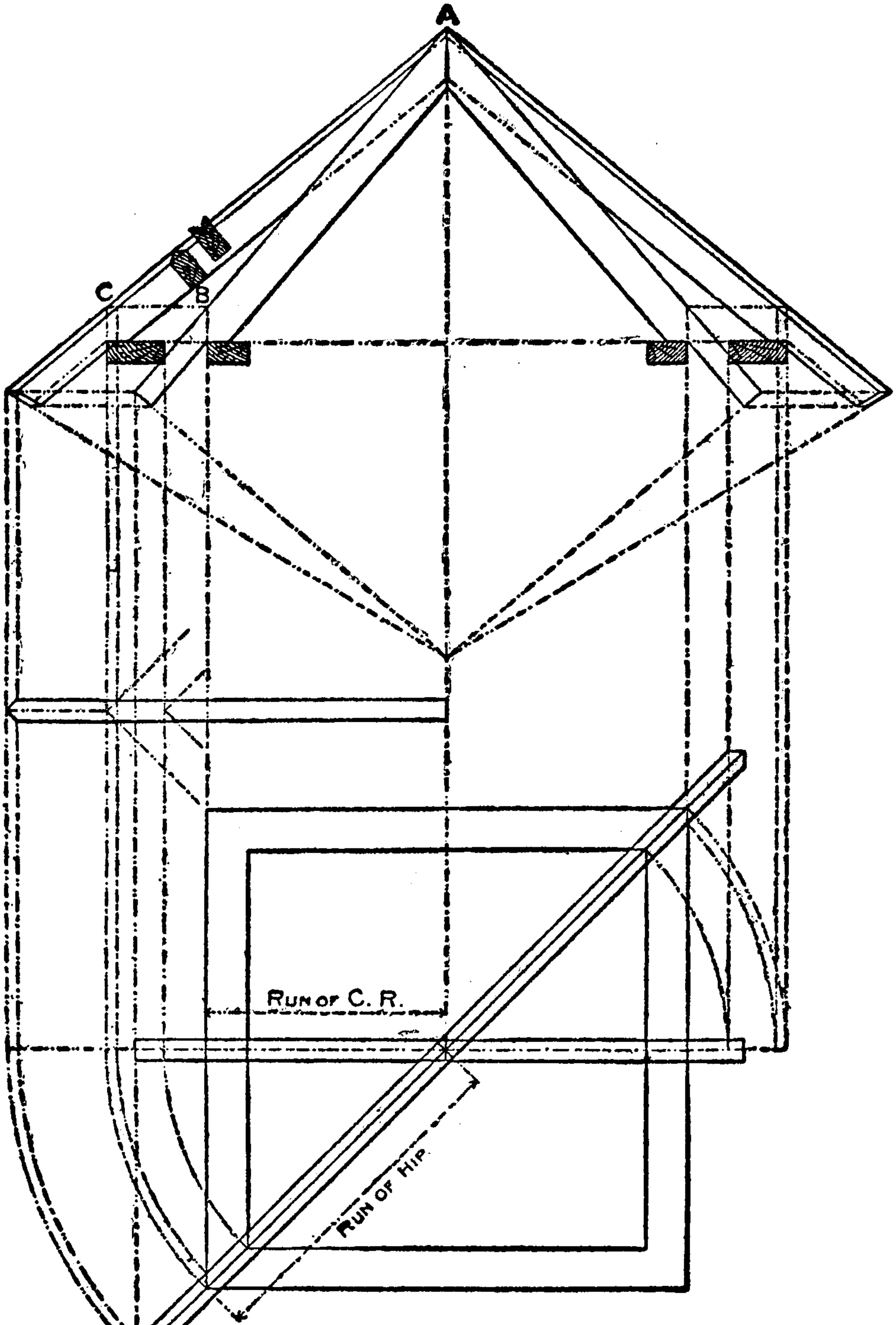

FIG. 32

the tongue, and 15 (length of the common rafter) on the blade.

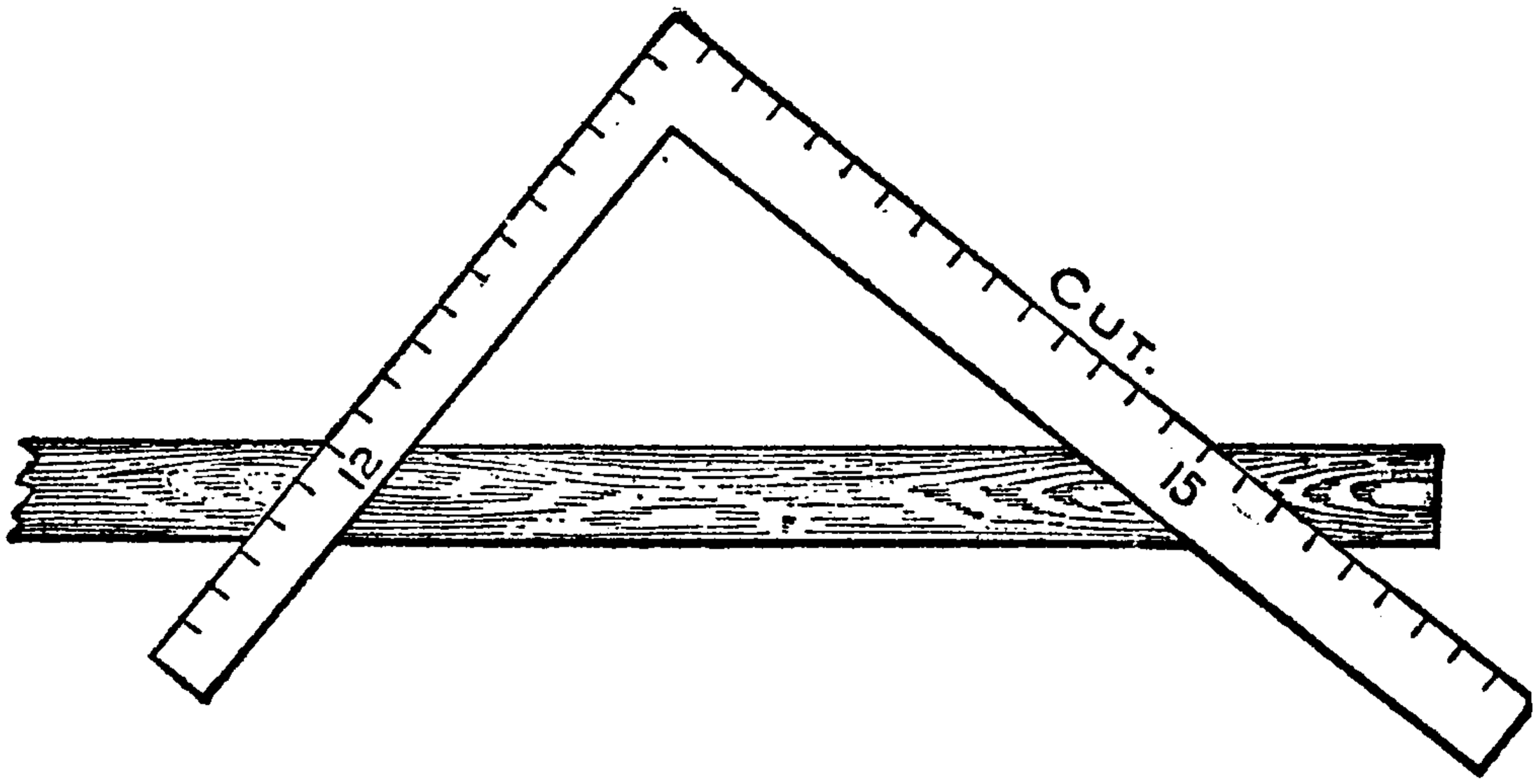

FIG. 33

Fig. 34 illustrates side cut of the octagon jack, 5 on the tongue and 15 on the blade.

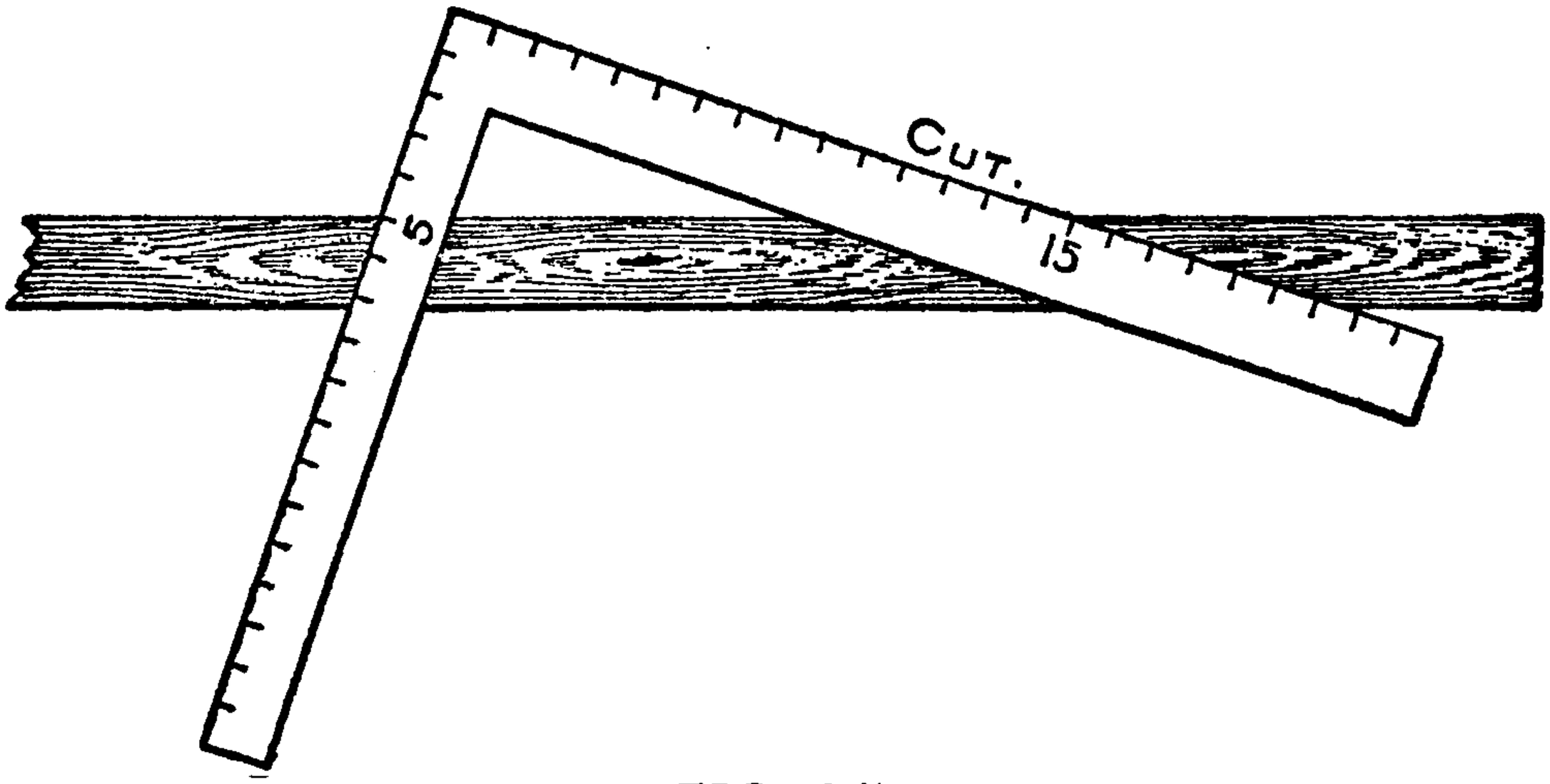

FIG. 34

Fig. 35 illustrates the side cut of the hip or valley, 17 on tongue, 19¼ (length of the hip) on the blade. The blade giving the cut in each case.

The latter, however, is for the unbacked rafter. If it has been previously backed, then apply the square with the above figures on the lower edge at bottom of the plumb cut, or apply the

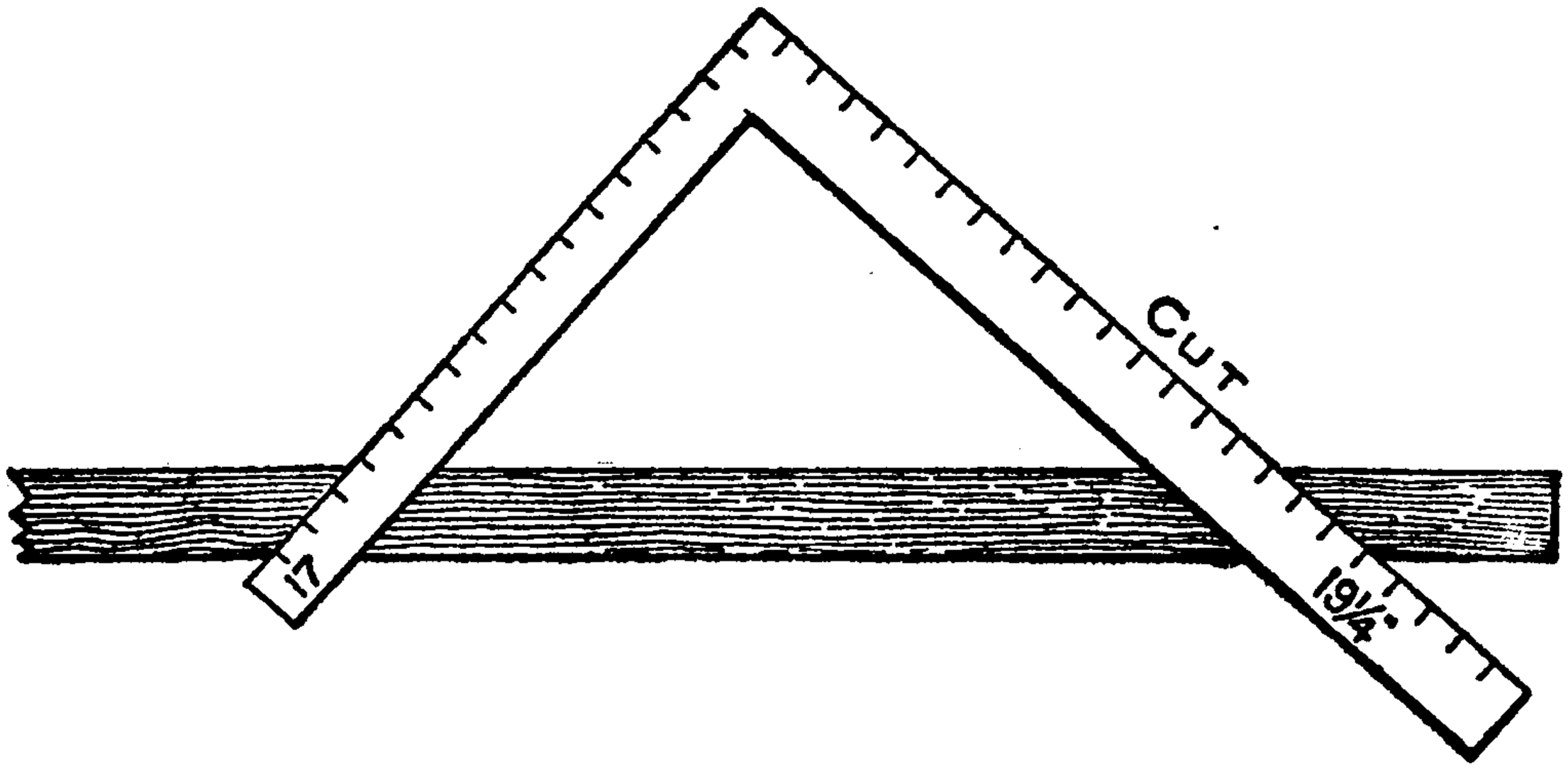

FIG. 35

square as for the jack, Fig. 33, to the backing line, which will give the same result as 17 and 19¼.

It is quite clear that when a workman cuts a common rafter he is also cutting a timber that would answer for a hip for a building of less span having the same rise, only taking some adjustment of the top bevel to fit against the ridge. This is quite plain, and if we refer to Fig. 36 we find that the common rafter for a 1-foot run becomes a hip for an 8½ inch run, and that a hip for a 1-foot run of the building becomes a common rafter for a 17-inch run. Therefore, the rule that applies to the common rafter also applies to the hip rafter, i. e., the run and rise taken on the square will give the seat and plumb cuts. The run and length of the rafter taken

on the square will give the side cuts, or taking the scale for a 1-foot run, Fig. 36, it is 12 on the tongue and the rise on the blade for the common rafter, and 17 on the tongue and rise on the blade

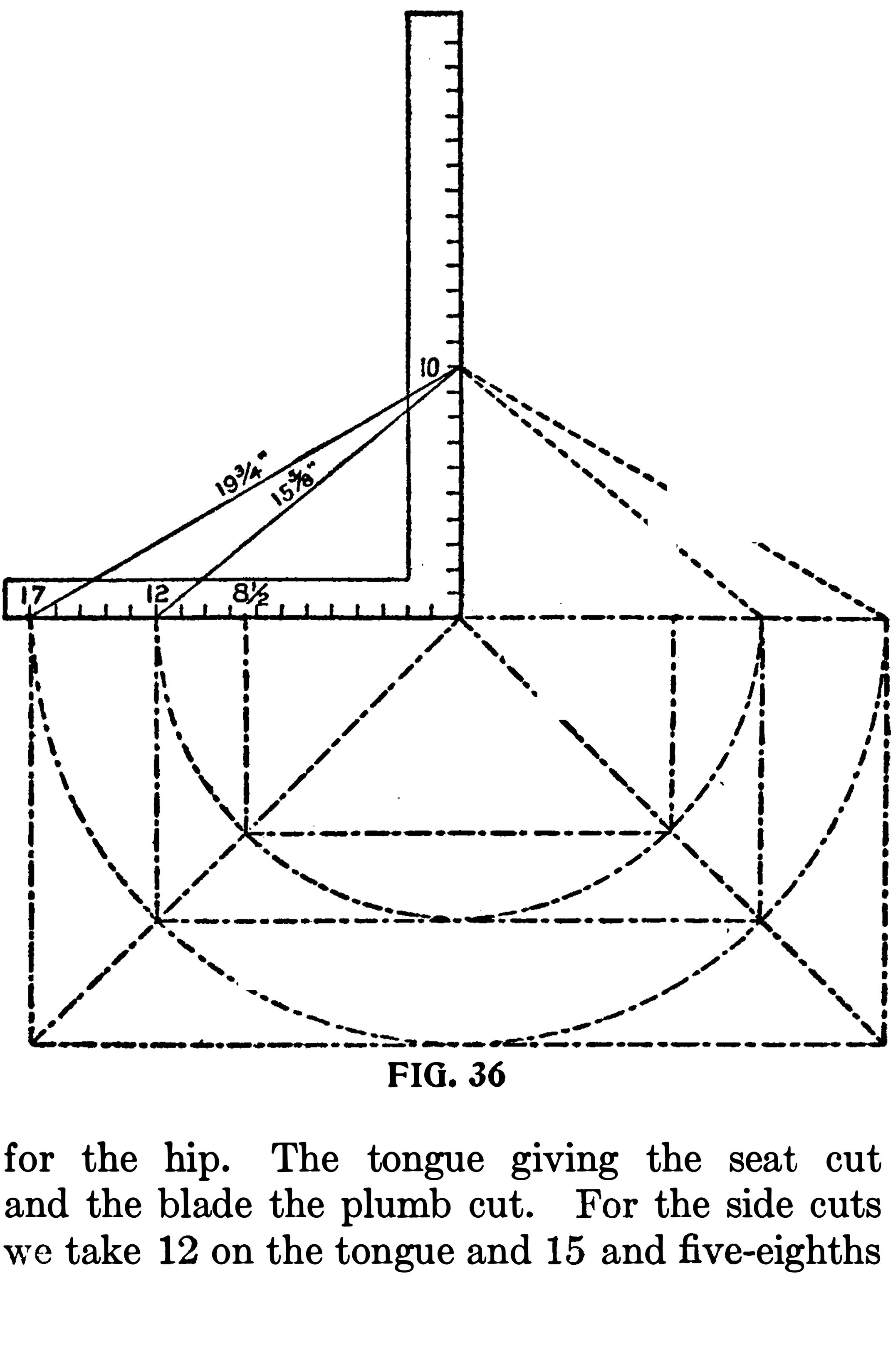

FIG. 36

for the hip. The tongue giving the seat cut and the blade the plumb cut. For the side cuts we take 12 on the tongue and 15 and five-eighths

inches on the blade, and the blade will give the side cut of the jack. Take 17 on the tongue and the length of the hip, 19¾ inches on the blade, and the blade will give the side cut of the hip. It would also be the side cut of the corresponding jack if it be a common rafter. Seventeen is used for a foot run of the hip rafter because the diagonal of a 12-inch square is practically 17 inches.

If we were to use 12 on the tongue for a foot run of the hip the rise to the foot would necessarily be less than 10 inches. In Fig. 37 we show what the difference is in the rise to the foot.

From 12 to 12 is the length of the run of the hip, and this, taken on a continued line of the run of the common rafter, and an equal rise of the common rafter, set off as at A, and a line from this to 12 on the tongue passes at 7 and one-

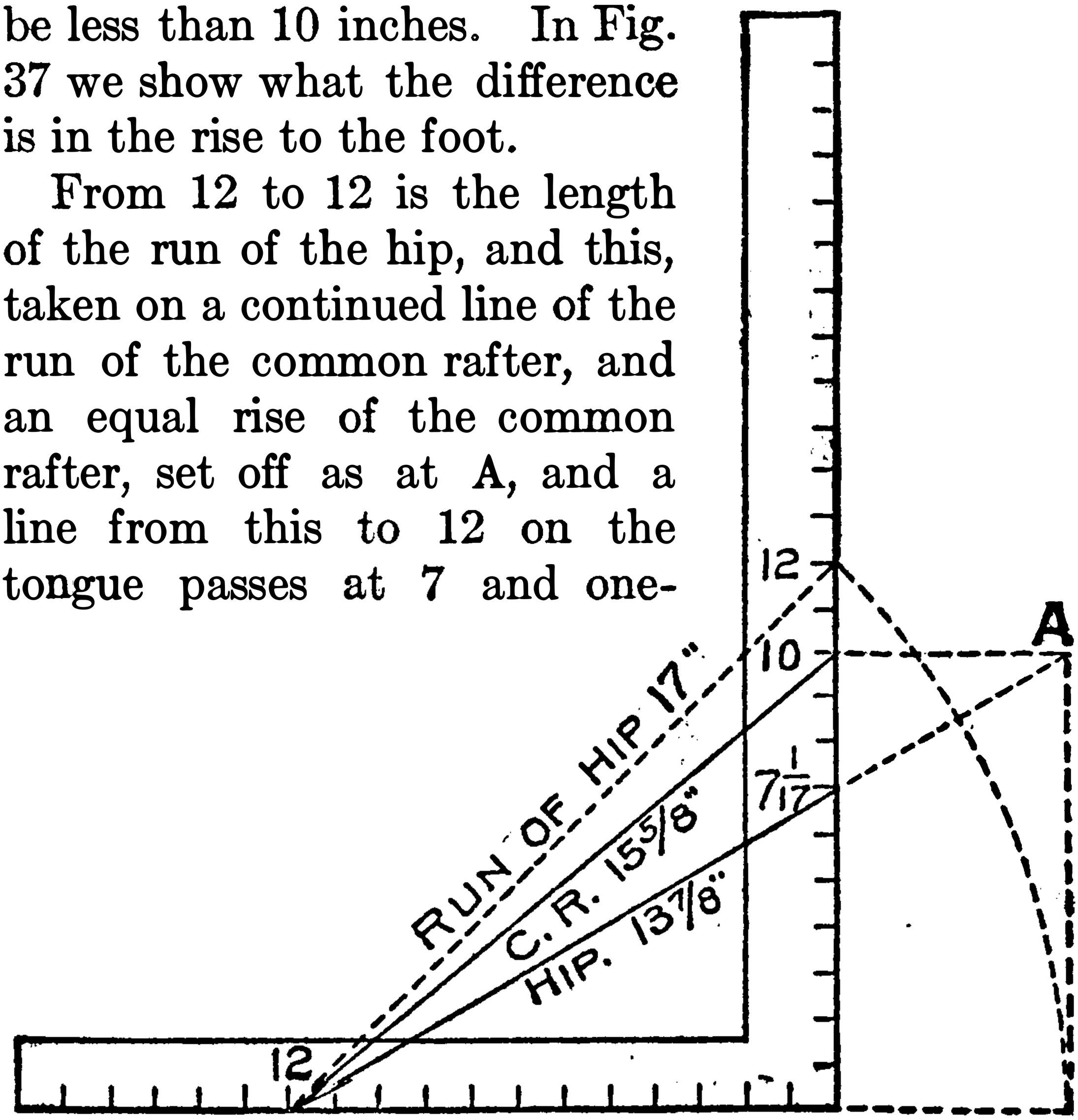

FIG. 37

seventeenth inches on the blade, because the common rafter having a rise of 10 inches to one foot, for one inch it would have ten-twelfths of an inch, while the hip would only have ten-seventeenths of an inch to one inch and for 12 inches it would be 12 times ten-seventeenths, equals 120 seventeenths, or 7 and one-seventeenth inches. Therefore the figures given in the second part of illustration would give the same cuts as those in the first, but the latter necessitates a calculation that ends in fractions—fractions not given on the square—and for that reason 17 is generally used for a foot run for the hips and valleys.

An Unequal Pitch.—In the matter of roofing over unequal pitches when there is no ridge and when all hips meet, the building being longer than it is wide, the backing of hips and their lengths and bevels would be a very easy matter if a drawing of the whole thing were made, but, to obtain these by the use of the square alone, is somewhat more difficult. Let us assume the building to be 18 feet wide and 28 feet long, and having a rise of 9 feet, then, by referring to Fig. 38, we show to one-inch scale the length, run, rise, seat, and plumb cuts for the hip and common rafters as follows: The run of the long way of the building is 14, and 9 for the narrow way, which we take on the blade and tongue respectively, as shown on square No. 1, and to this apply square No. 2, as shown. A D equals the run of the hip. A E equals the rise and E D

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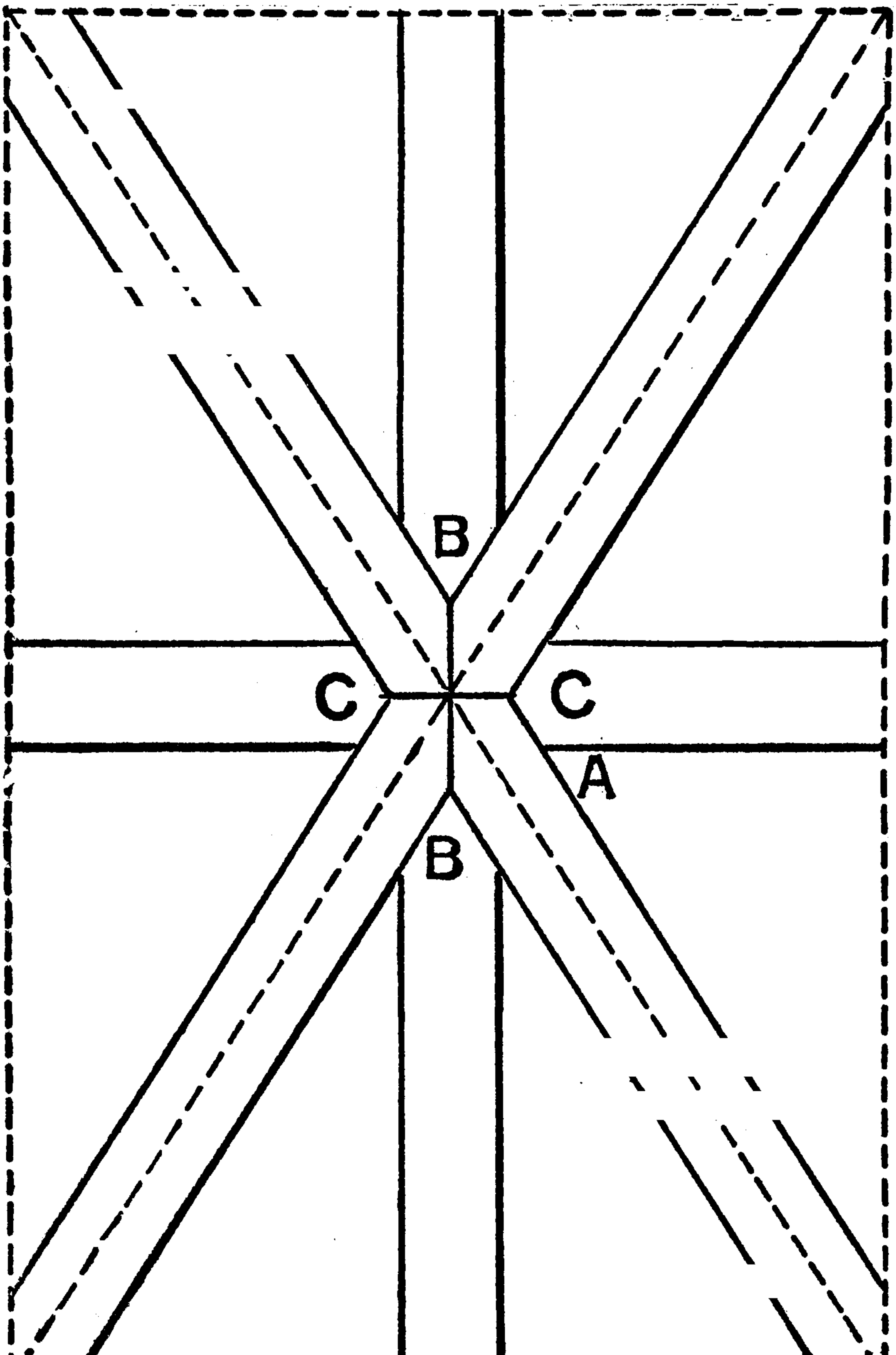

FIG. 39

sary that the common rafters must cut back so as to fit in the angle formed by the hips. The proper deduction for this is shown in Fig. 40 by

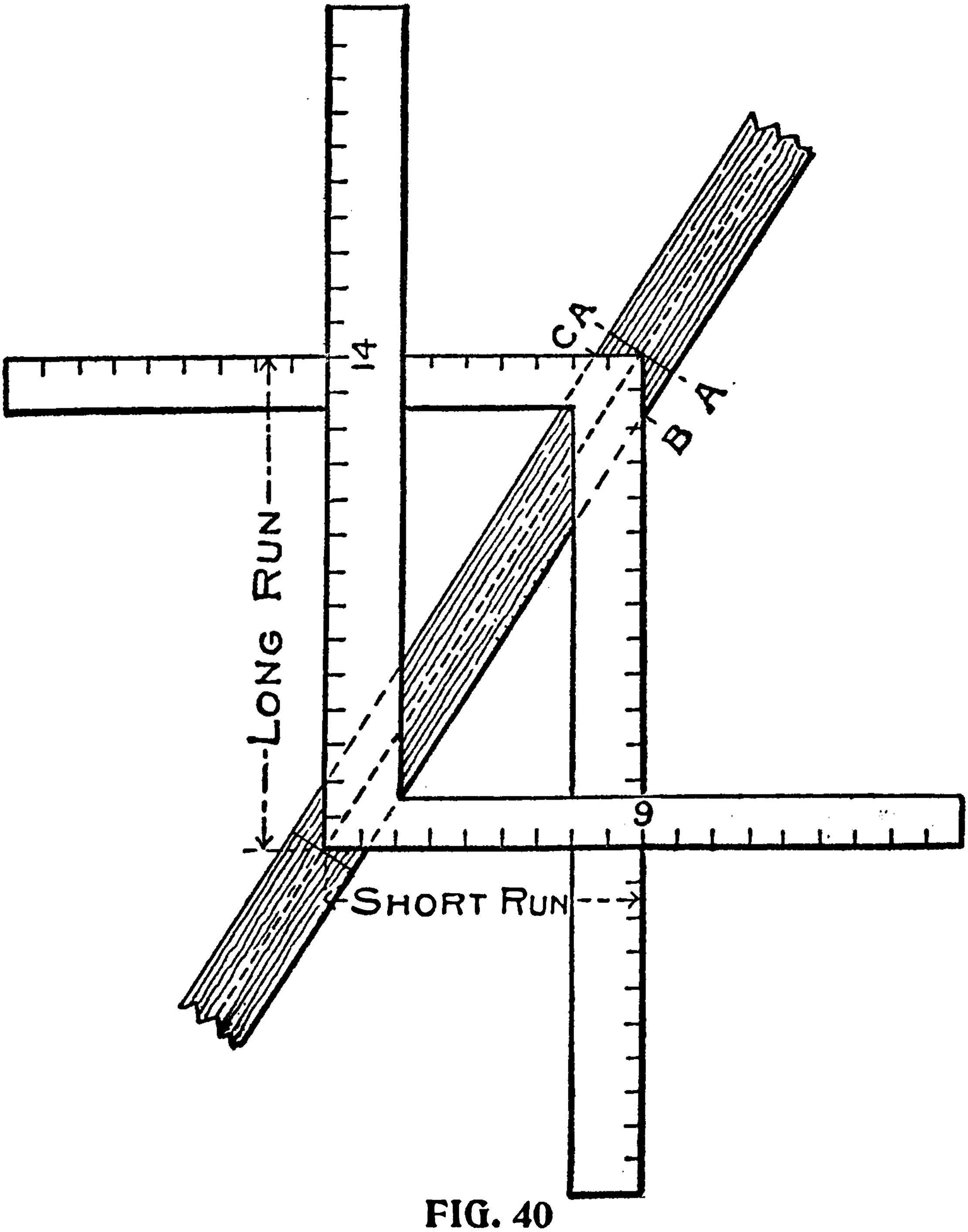

FIG. 40

placing two squares on the back of the rafter, with the heel or corner of the squares resting on the center line. The distance from the corner

of the square to B measured square back (at right angles) from the plumb bevel, as shown in Fig. 38, will locate the point of the long common rafter at B in Fig. 39. Proceed in like manner for the short common rafter, taking the distance from the corner to C, and for the side cuts, take 14 on the tongue and the length of the short common rafter C E on the blade—the blade will give the cut at A C in Fig. 39. The reader will observe that this angle is the same as that for the side of the jack. Proceed in like manner for the long common rafter side, using 9 on the tongue and B E on the blade. These same figures will give the side cuts of the hip, provided hip has been previously backed. Taking the last for example, the reader will observe that 9 on the tongue and B E on the blade, the square would lay on the plane of the backing and the blade giving the cut along the line BB in Fig. 39, or these cuts may be found by measuring square back from a plumb bevel at points A and A, Fig. 40, the distance A C and A B, which will give the proper plumb cut at the sides and intersecting the line A A at the center. These same distances, A C and A B, but transferred to opposite sides, set off on the seat cut or a parallel with it, will give the gauge points on the side of the hip for the backing.

To Find the Length of the Jacks.—The lengths of the jacks may be found by dividing the length of the common rafter by the number of the spacings for the jacks; the quotient will be the common difference.

Hip Roof Framing

We have already referred to the great variety of problems—many of them of considerable complexity, depending on the greater or less complexity of the kind of roof selected for the structure—that arise when the carpenter is confronted with the problem of putting on the roof. These problems will vary with the number of hips and valleys, the pitch, length of run, etc., but the fundamental principles involved in their solution are not many; and a familiarity on the part of the carpenter with the steel square will enable him to solve them all.

A Formula in Figures.—We first lay off common rafter, which has been previously explained; but deeming it necessary to give a formula in figures to avoid making a plan, we take one-third pitch. This pitch is one-third the width of building, to point of rafter from wall plate or base. For example, always use 8, which is one-third of 24, on tongues for altitude; 12, one-half the width of 24, on blade for base. This cuts common rafter. Next is the hip-rafter. It must be understood that the diagonal of 12 and 12 is 17 in framing, and the hip is the diagonal of a square added to the rise of roof; therefore we take 8 on tongue and 17 on blade; run the same number of times as common rafter, these figures

also give the seat and plumb cut of the hip. To cut jack rafters, divide the number of openings, for common rafter. Suppose we have five jacks, with six openings, our common rafter is 12 feet long, each jack would be two feet shorter. First 10 feet, second 8 feet, third 6 feet, and so on. The plumb cut is the same as for the cut of common rafter; seat cut also the same as for the common rafter. To cut miter to fit hip. Take half the width of building on tongue and length of common rafter on blade; blade gives cut, or the same result may be found by taking the diagonal of 12 and 8, which is 14 7-16, then take 12 on tongue, 14 7-16 on blade; blade gives cut.

Side Cut of the Hip.—In connection with the hip there must be another cut considered, called the side cut of the hip, though the angle

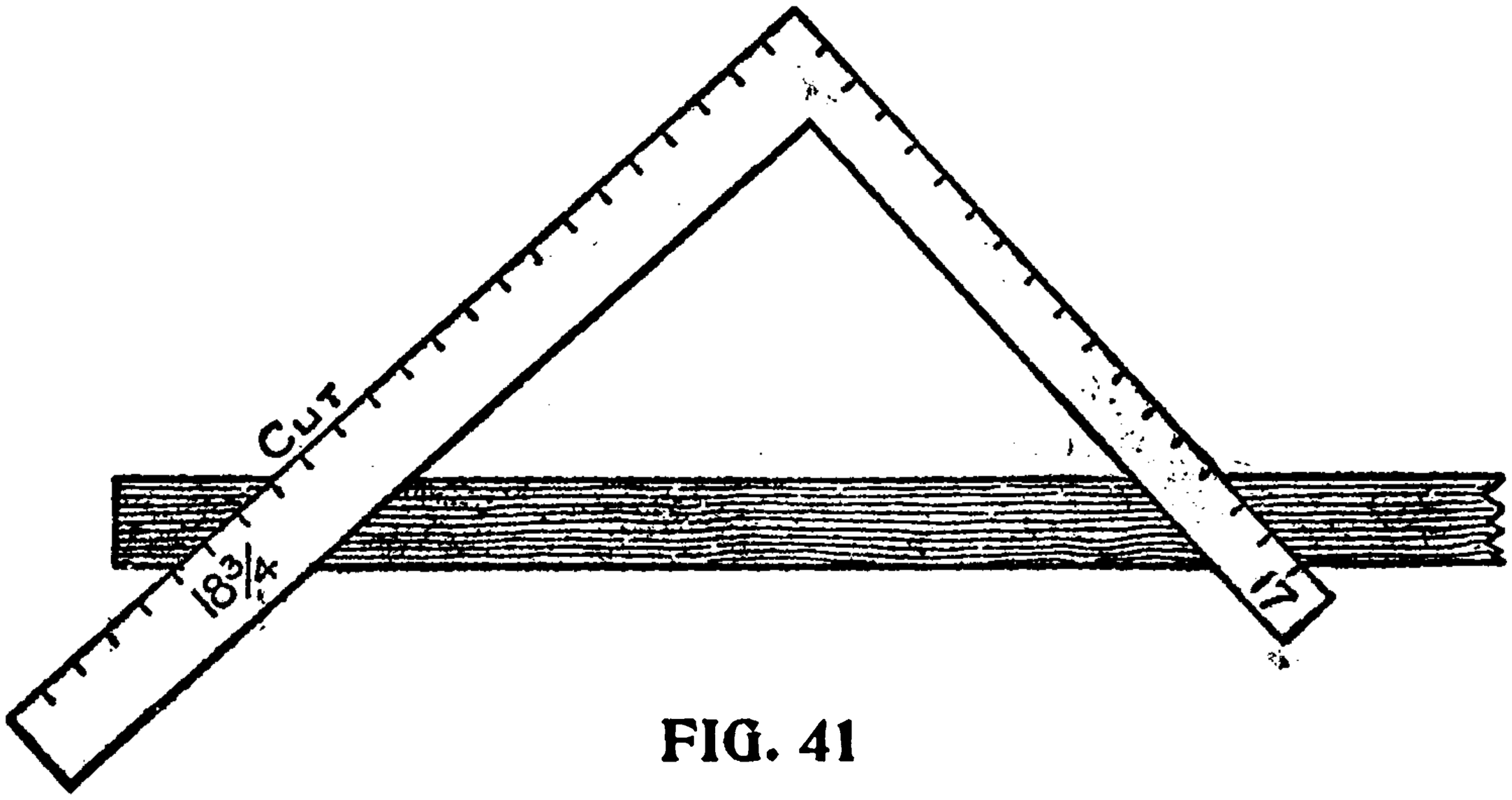

FIG. 41

to obtain this cut is across the top or back of the rafter. Were there no slope to the roof, this angle where it meets the ridge pole would be an

angle of 45 degrees, but when a slope is given this angle becomes more acute. The rule is, take the length of the hip on the blade and its run on the tongue, the blade gives the cut or take 17 on the tongue and 18¾ on the blade, blade gives the cut as shown in Fig. 41.

Beveling of Hip Rafter.—The hip-rafter should be beveled so as to be in plane of the common rafter; height of hip on tongue, length of hip on

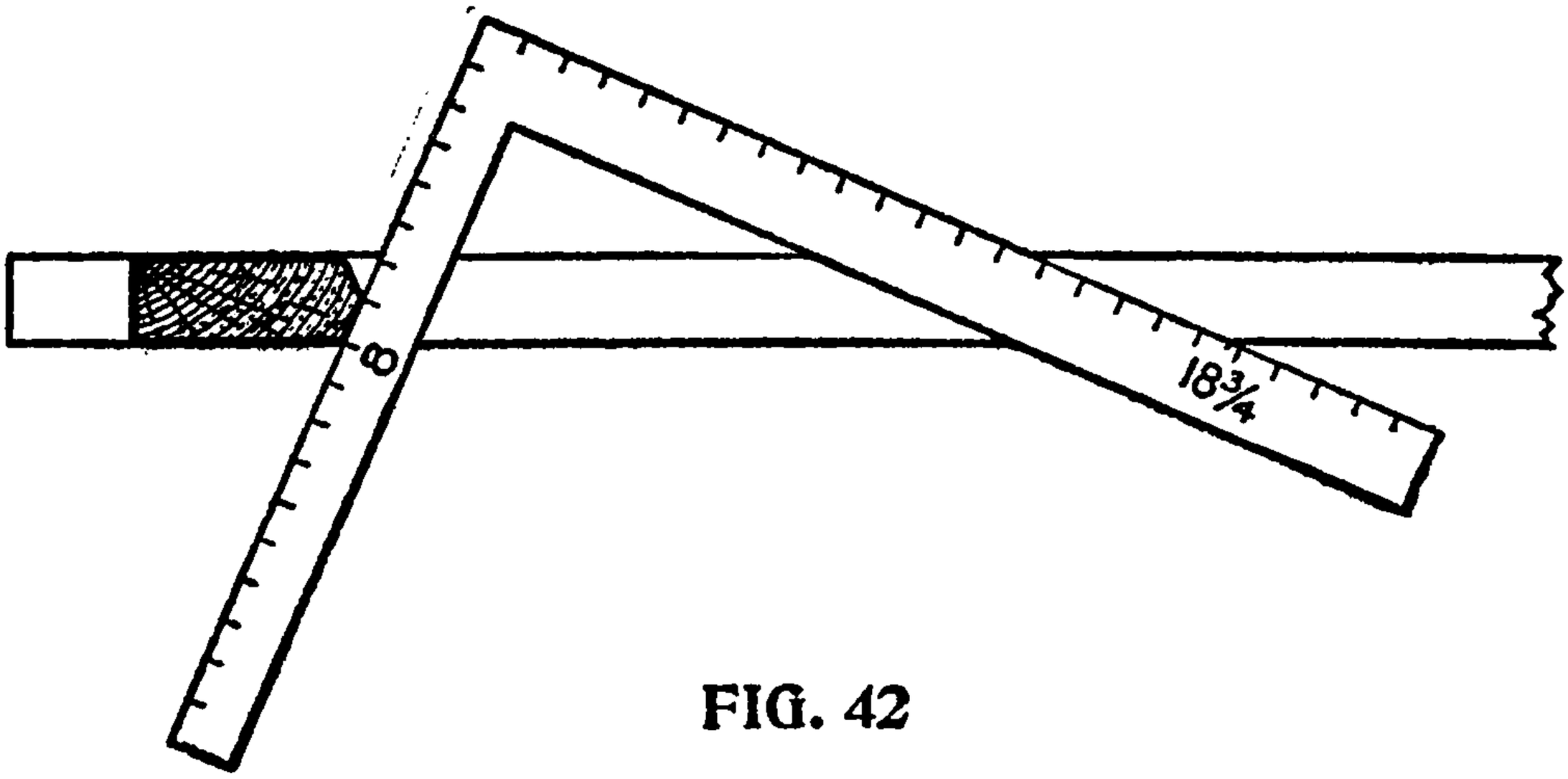

FIG. 42

blade; tongue gives bevel, or we take 8 on tongue, 18¾ on blade; tongue gives bevel, as shown in Fig. 42. These figures will cover all cuts in putting on cornice and sheathing.

To Cut Bed Moulds For Gable to fit under cornice; take half the width of the building on tongue, length of common rafter on blade; blade gives cut; machine mouldings will not member, but this gives a solid joint; and to member properly it is necessary to make the mouldings by hand, the diagonal plumb cut differences.

To Cut Planceer, to Run Up Valley: Take

height of the common rafter on tongue, length of rafter on blade; tongue gives the miter cut. The side cut takes the length of common rafter on blade, and run on tongue; tongue gives cut.

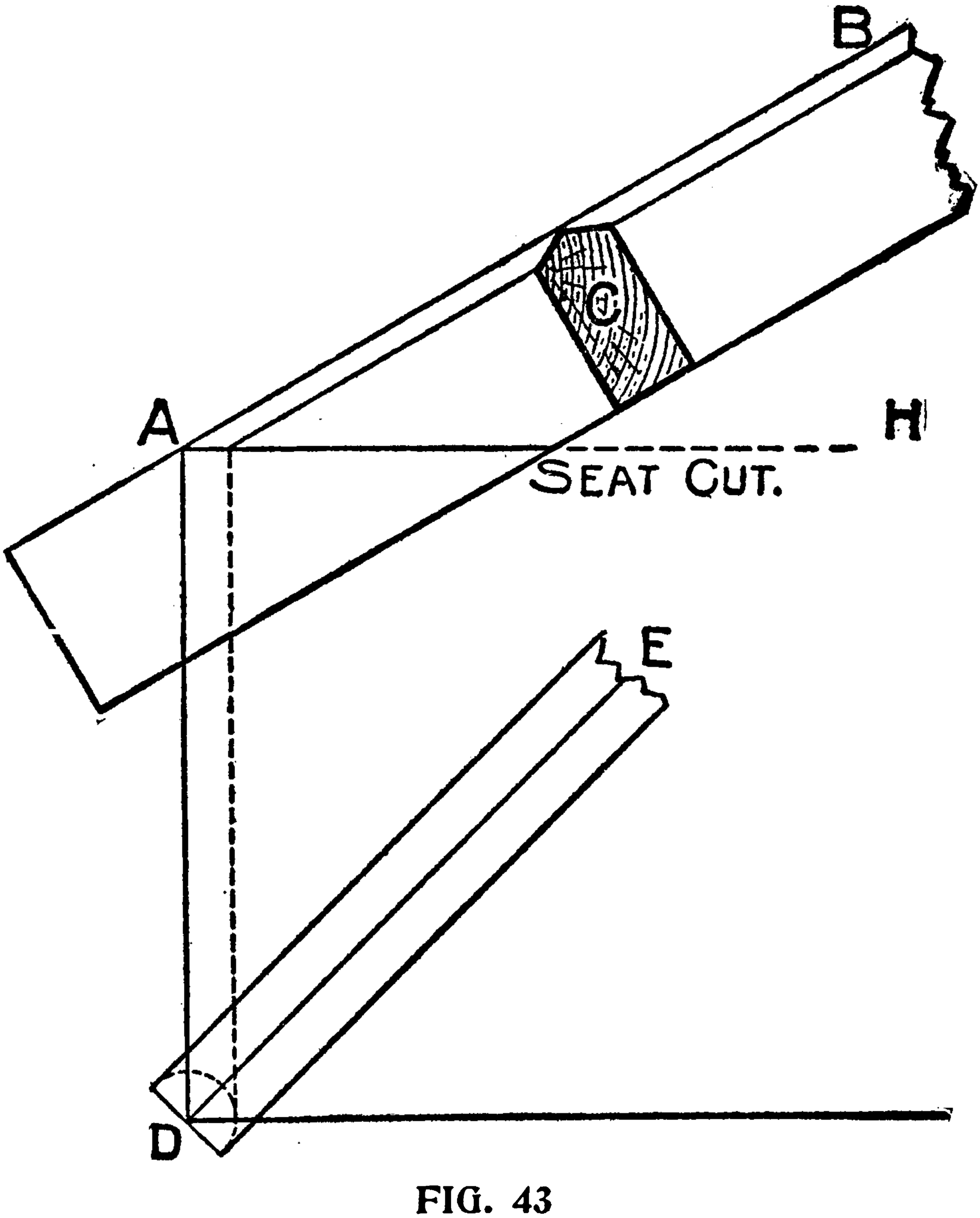

FIG. 43

These figures give the cuts regardless of width of building.

Fig. 43 applies to backing of hips where the

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half the width. Bisect B C in a, and join A a, D a. From a set off ac, ad equal to the height of the roof ab, and join Ad, Dc; then Ad, Dc are the length of the hip-rafters. To find the backing:

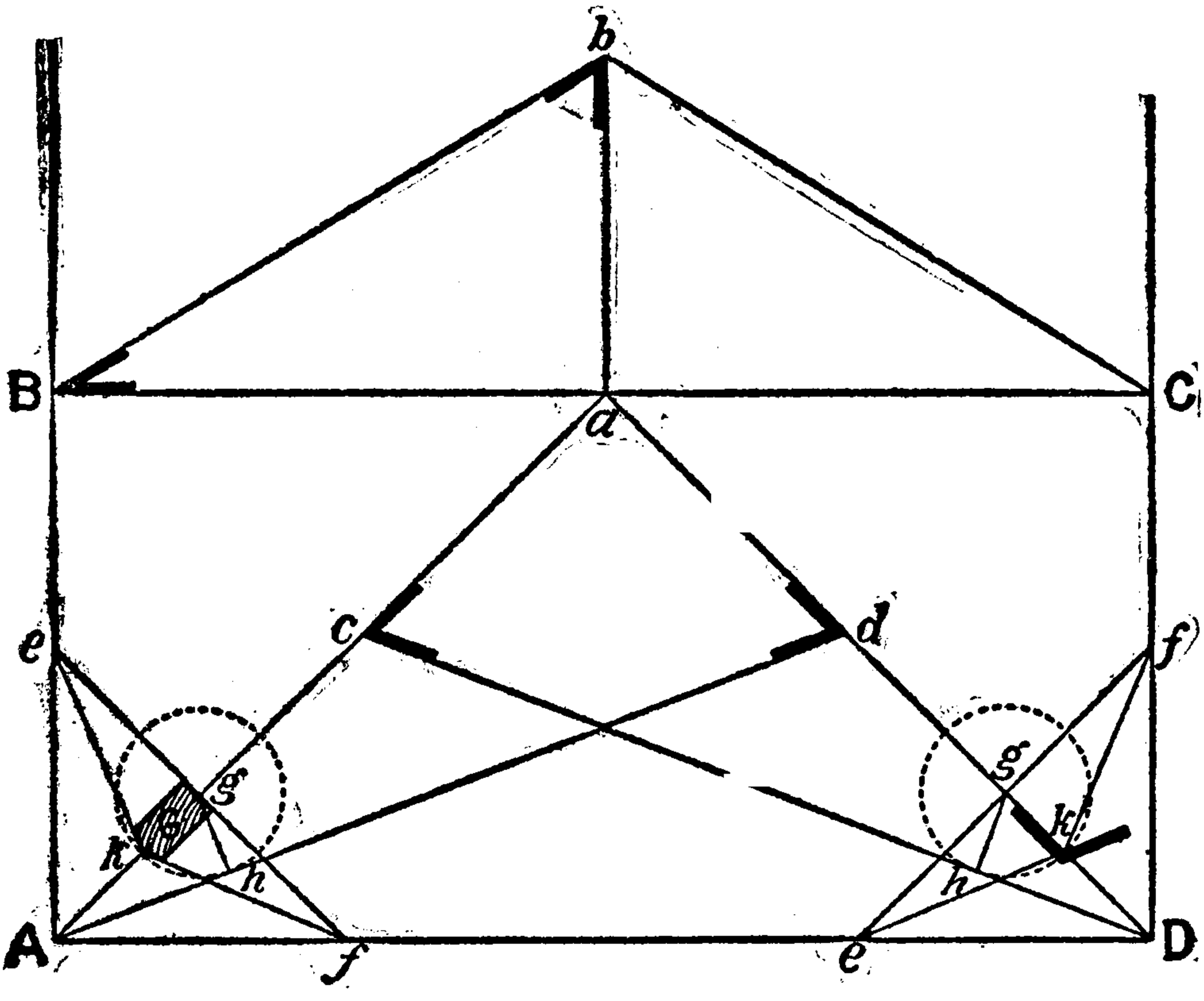

FIG. 44

From any point h in Ad, draw the perpendicular hg, cutting Aa in g; and through g draw perpendicular to Aa the lines ef, cutting AB, AD in e and f. Make gk equal to gh, and join ke, kf; the angle ekf is the angle of the backing of the hip-rafter G.

Fig. 45 shows the method of obtaining the backing of the hip where the plan is not right angled.

Bisect AD in a, and from a describe the semi-circle AbD; draw ab parallel to the sides AB, DC, and join Ab, Db, for the seat of the hip-rafters. From b set off on bA, bD the lengths bd, be, equal to the height of the roof bj, and join Ae, Dd, for the lengths of the hip-rafters. To find the backing of the rafter: In Ae, take any point

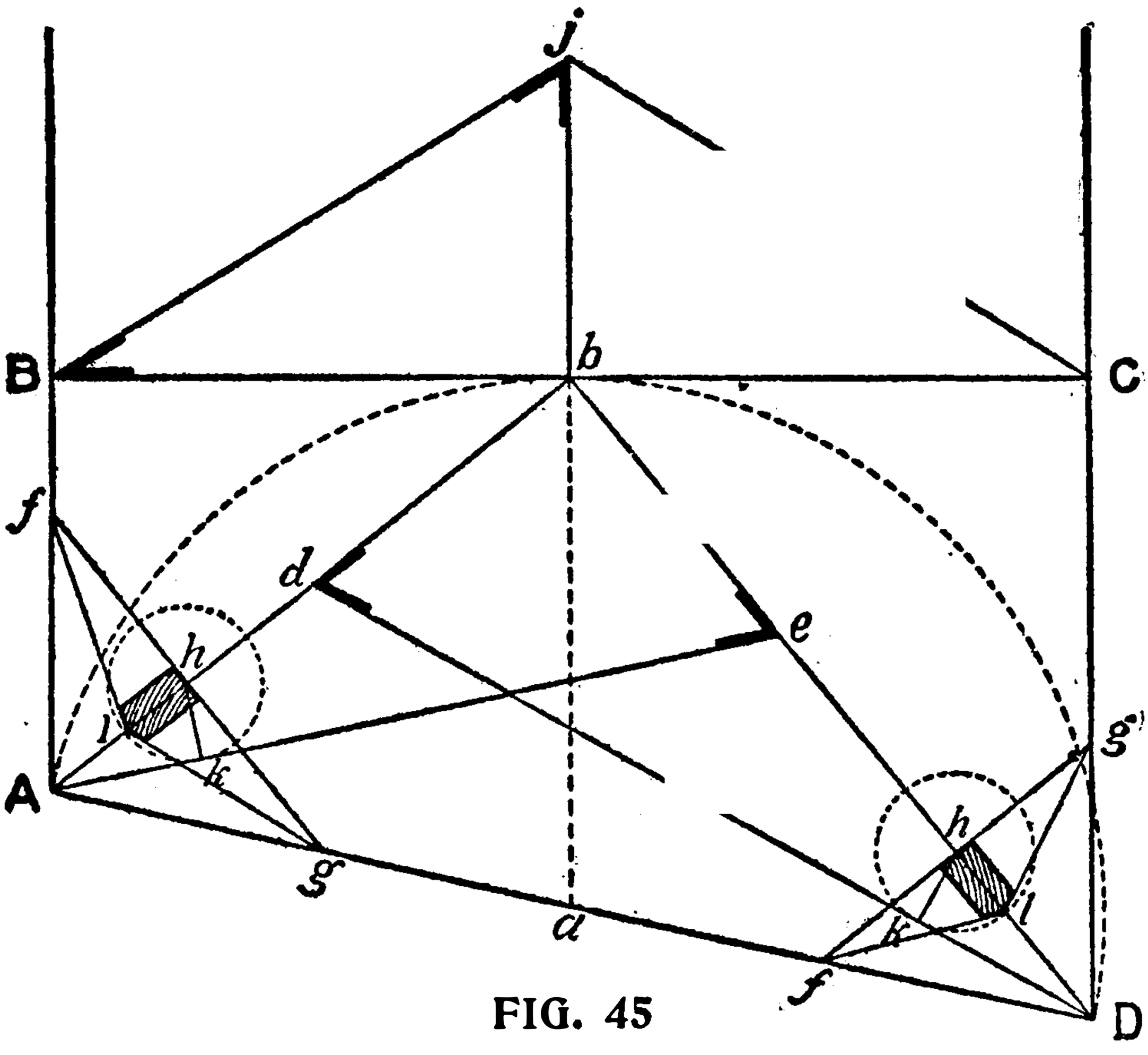

FIG. 45

k, and draw kh perpendicular to Ae. Through h draw fhg perpendicular to Ab, meeting AB, AD, in f and g. Make l equal to hk, and join fl, gl; then flg is the backing of the hip.

How to Find the Shoulder of Purlins.—Fig. 46 shows how to find the shoulder of purlins:

First, where the purlin has one of its faces in the plane of the roof, as at E. From c as a

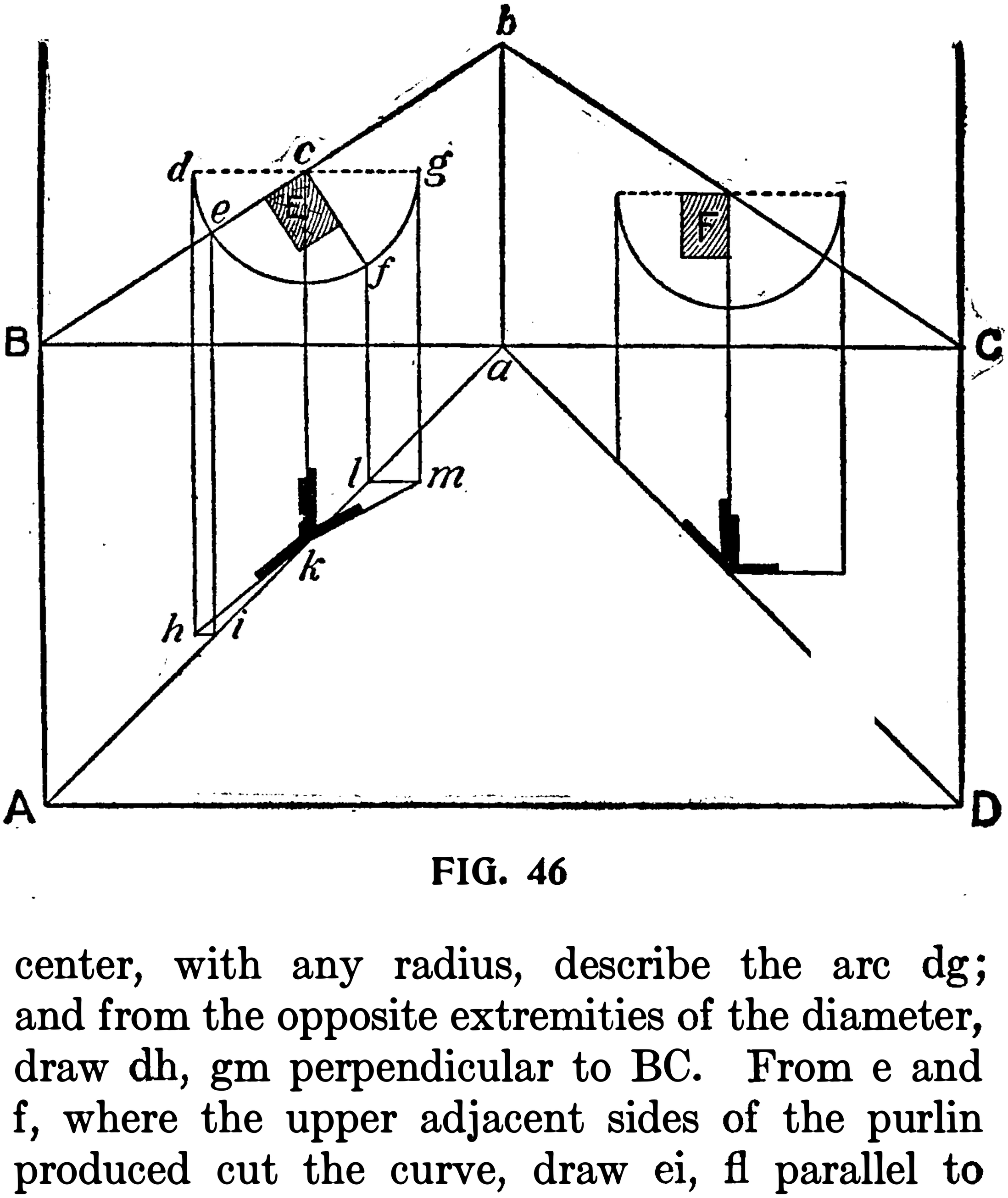

FIG. 46

center, with any radius, describe the arc dg; and from the opposite extremities of the diameter, draw dh, gm perpendicular to BC. From e and f, where the upper adjacent sides of the purlin produced cut the curve, draw ei, fl parallel to dh, gm; also draw ck parallel to dh. From l and i draw lm and ih parallel to BC, and join kh, km. Then ckm is the down bevel of the purlin, and ckh is its side bevel.

When the purlin has two of its sides parallel

to the horizon. This simple case is worked out at F. It requires no explanation.

When the sides of the purlin make various angles with the horizon. Fig. 47 shows the ap-

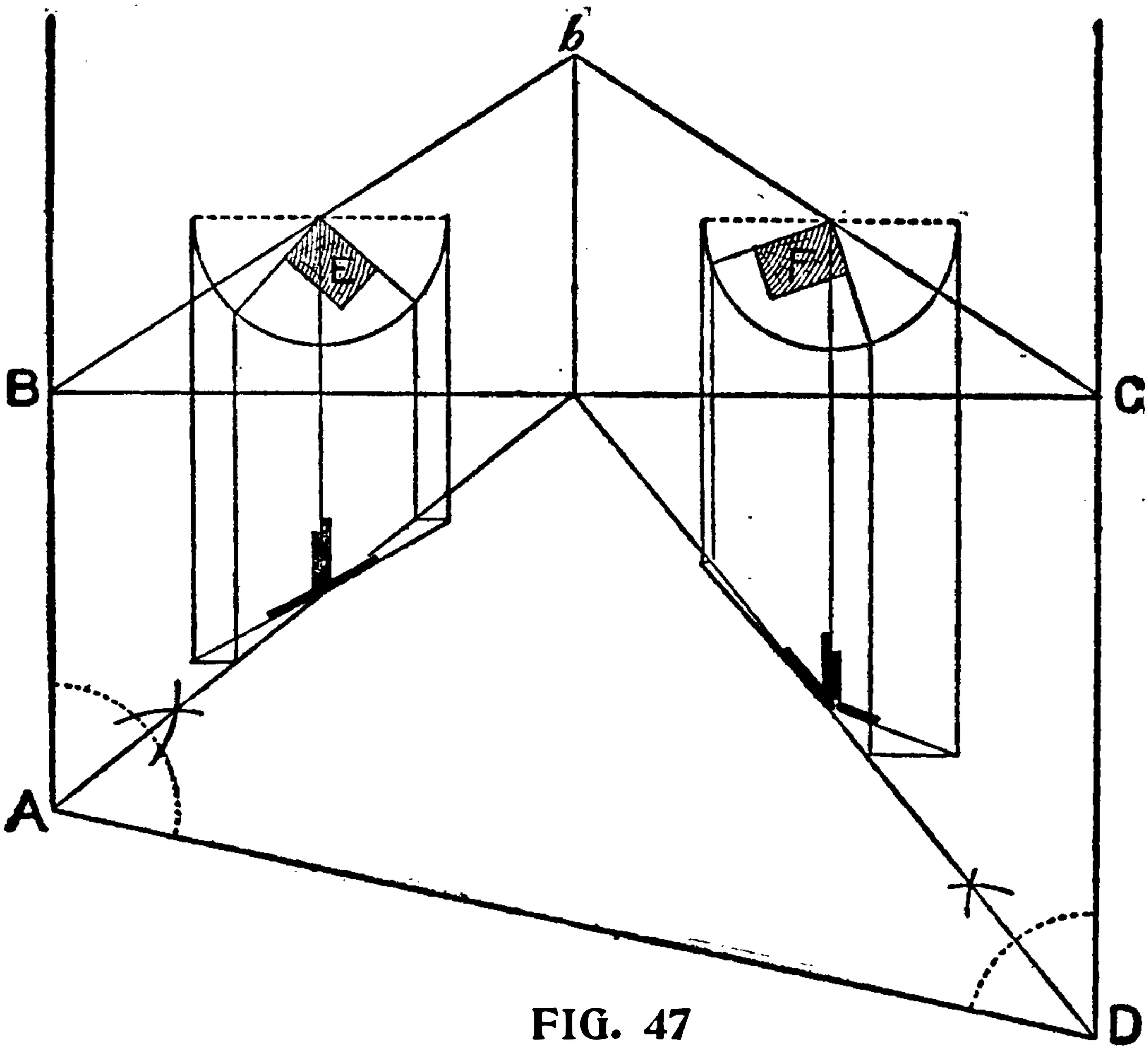

FIG. 47

plication of the method described in Fig. 46 to these cases. See also Fig. 49.

How to Pierce a Circular Roof With a Saddle Roof.—It somtimes happens, particularly in rail-road buildings, that the carpenter is called upon to pierce a circular or conical roof with a saddle roof, and to accomplish this economically is often the result of much labor and perplexity if a correct method is not at hand.

The following method, shown in Fig. 48, is an excellent one, and will no doubt be found useful in cases such as mentioned.

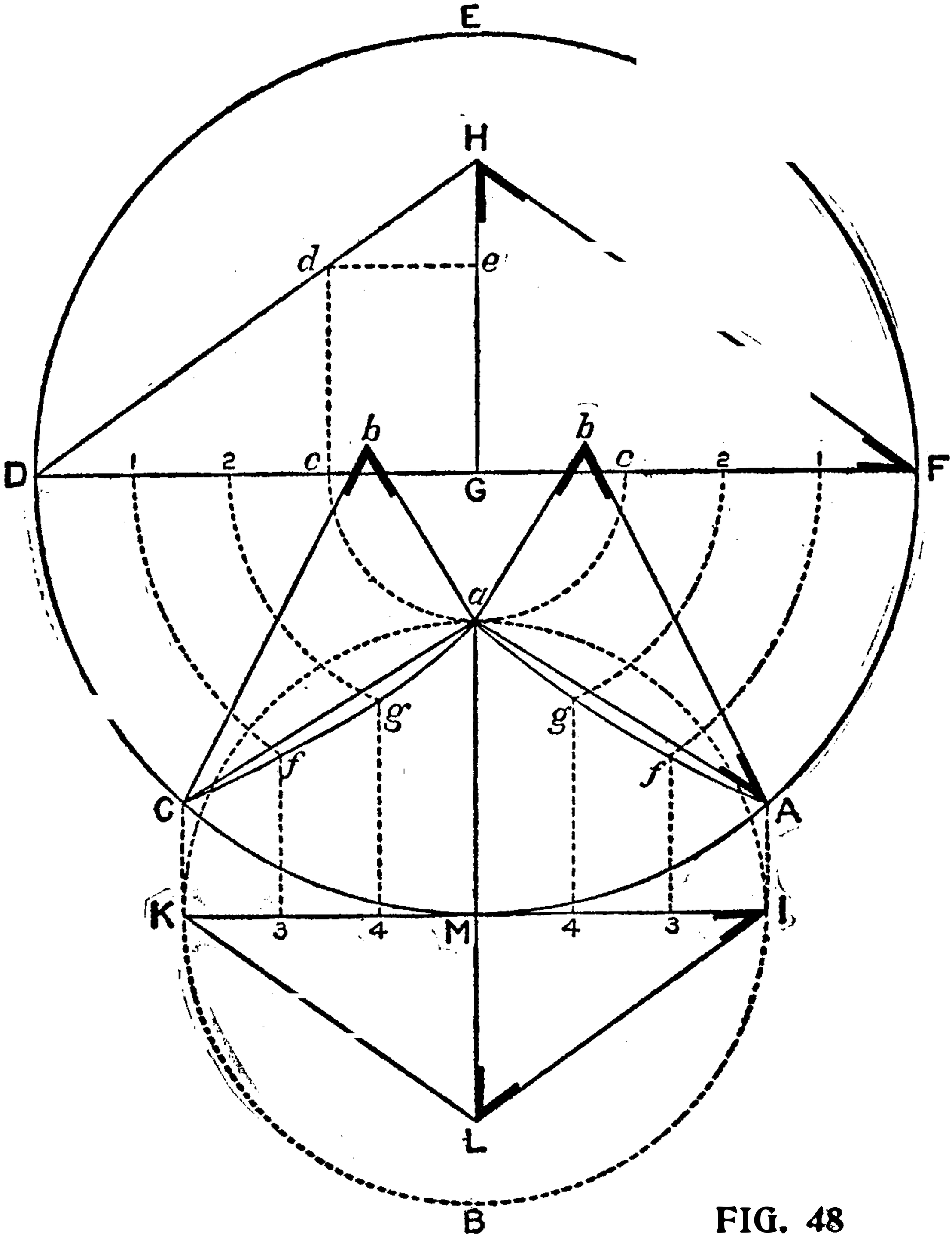

FIG. 48

Let DH, FH, be the common rafters of the conical roof, and KL, IL the common rafters of

the smaller roof, both of the same pitch. On GH set up Ge equal to ML, the height of the lesser roof, and draw ed parallel to DF, and from

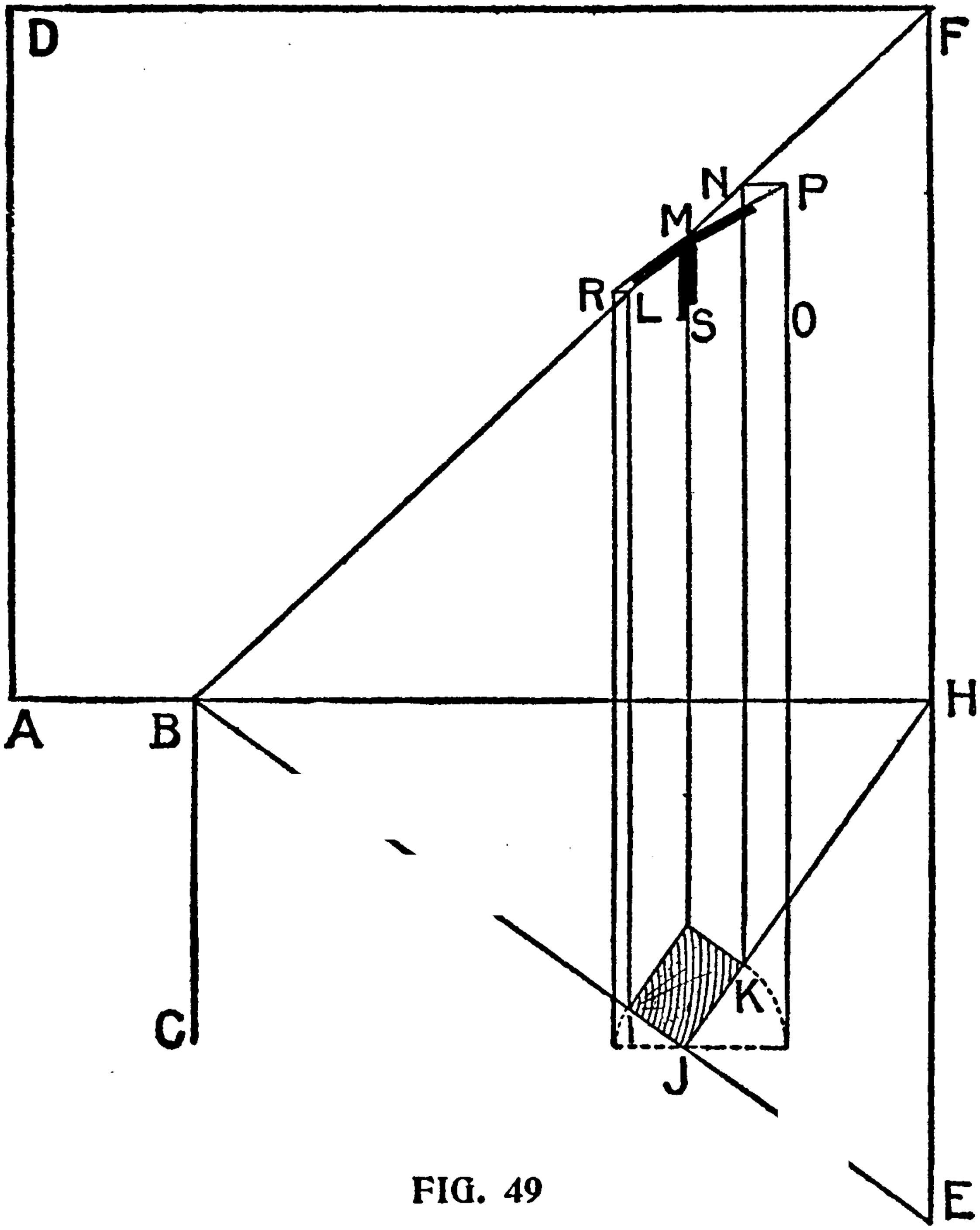

FIG. 49

d draw cd perpendicular to DF. The triangle Ddc, will then by construction be equal to the

triangle KLM, and will give the seat and the length and pitch of the common rafter of the smaller roof B. Divide the lines of the seats in both figures, Dc, KM, into the same number of equal parts; and through the points of division in E, from G as a center, describe the curves ca, 2g, 1f, and through those in B, draw the lines 3f, 4g, Ma, parallel to the sides of the roof, and intersecting the curves in fga. Through these points trace the curves Cfga, Afga, which will give the lines of intersection of the two roofs. Then to find the valley rafters, join Ca, Aa; and on a erect the lines ab, ab perpendicular to Ca and Aa, and make them respectively equal to ML; then Cb, Ab is the length of the valley rafter.

In Fig. 49 is shown another method of finding the bevels of the purlins at the hip or valley.

Let ABC be the eaves of roof, DF and FE the ridges, BF the valley or plan, HE the rise and BE the pitch of roof. Mark the purlin IJK to a large scale—full size if possible—and draw IL, JM, and KN all parallel to EF; make SO equal to JK; draw OP, and draw NP parallel to DF; join MP; and the bevel SMP will apply on the side of purlin. Make RS equal to JI; draw LR; and the bevel SMR will apply on top of purlin.

Illustration of Roof Pitches.—Mr. Woods' illustration in Fig. 49a, contains a whole volume in roof framing. His explanation of the figure is as follows:

In this illustration we show a line for every

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must be double the run, or 24 inches, which is the length of the blade of the square. Then the first inch in rise on the blade must be that proportion to its own length, and produces one-twenty-fourth pitch, the second inch, one-twelfth pitch, the third one-eighth pitch, and continue to the twenty-fourth inch, when it becomes full. The twenty-fifth inch rise would therefore be one and one-twenty-fourth pitch, which is simply a repetition of the above pitches with a one prefixed till it gets up to 48 inches, when it takes on another pitch and represents two pitches, and continues on and on, getting fuller and fuller, but would never stand straight up, because the run remains the same.

The fractional pitch lines for the common rafter are shown for each inch in rise up to the full pitch, and their lengths are expressed in decimal figures to the one-hundredth part of an inch, while to the right of the blade the same is expressed for the corresponding octagon and for the common hip or valley for a square-cornered building, which are reckoned from 13 and 17 on the tongue respectively. However, neither is absolutely correct, though near enough as far as the cuts are concerned. The greater deviation being in the hip for the square-cornered building. It lacks .0295 of being 17 inches and represents the run of the hip to a 12-inch run of the common rafter. Its true length being 16.9705 inches, this is the length from which we have reckoned for the lengths of the hips instead of 17, as is the

usual custom. This may seem a trifling difference, and so it is in a short run and low pitches; but suppose it is for iron construction. To begin with, the shortage of each foot in run with the common rafter is .0295 of an inch; added to this the gain it would have in the pitch, which would be .015 of an inch by the time it got up to the full pitch for the common rafter; and this added to the .0295 to start with would be a difference of .0445 of an inch to the foot in run with the common rafter. Now supose the run to be 18 feet; 18 x .0445 = .8+, or 19-24 of an inch difference; or, if no account was made of the gain in pitch, the .0295 of an inch in the run would amount to over half an inch in the length of the hip alone. This is a common error and while it is not much and probably would never be noticed in wood construction, it is well to know this discrepancy and guard against it when the occasion demands, and for that reason we give the correct amounts. The shortage in the octagon is not so pronounced. Instead of it being in the run, it is the tangent that is lacking the same amount, it being 4.9705 instead of 5 inches. This coming as it does cannot affect the length of the rafter nearly so much as in the above.

We explain this shortage better by referring to that part of the illustration in Fig. 49a showing the plan of a combination square and octagon frame with the heel of the steel square resting at the center. From this it will be seen that the two outer circles catch the corners of the frame

and seemingly intersecting the tongue at 13 and 17 and represent the figures to use on that member for the seat cuts, but the true length of the run of the hip is 16.9705 and that for the tangent of the octagon is 4.9705.

Reckoning by Degrees.—Angles are formed by the divisions of the circle, called degrees, of which it contains 360, and these parts are again divided into 60 parts, called minutes, and these parts are again divided into 60 parts, called seconds. From this it will be seen that there are many fractional parts, and if used for the pitches would result in fractions in the lineal measurement of the rise given the roof. Only the 45 degree is without a fraction on the blade of the square when using 12 on the tongue. Besides, there is no way of arriving at the measurement of same without a problem of no small means in trigonometry or the use of a protractor to arrive at the desired angle from which to take the measurements by scale.

In looking up the subject we fail to find pitch as applied to the roof defined in any of the encyclopedias other than by the degrees given the incline of the roof. Therefore, it is more than probable, to avoid these troublesome fractions, custom has settled on taking a proportion of the span for the rise. Thus, knowing the measurements of two of the factors (run and rise), the third (pitch) is easily arrived at by scale and from their measurements, the various angles for the cuts may be obtained with the steel square with-

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spaces, which will make the divisions five degrees apart, and by dividing these spaces into five

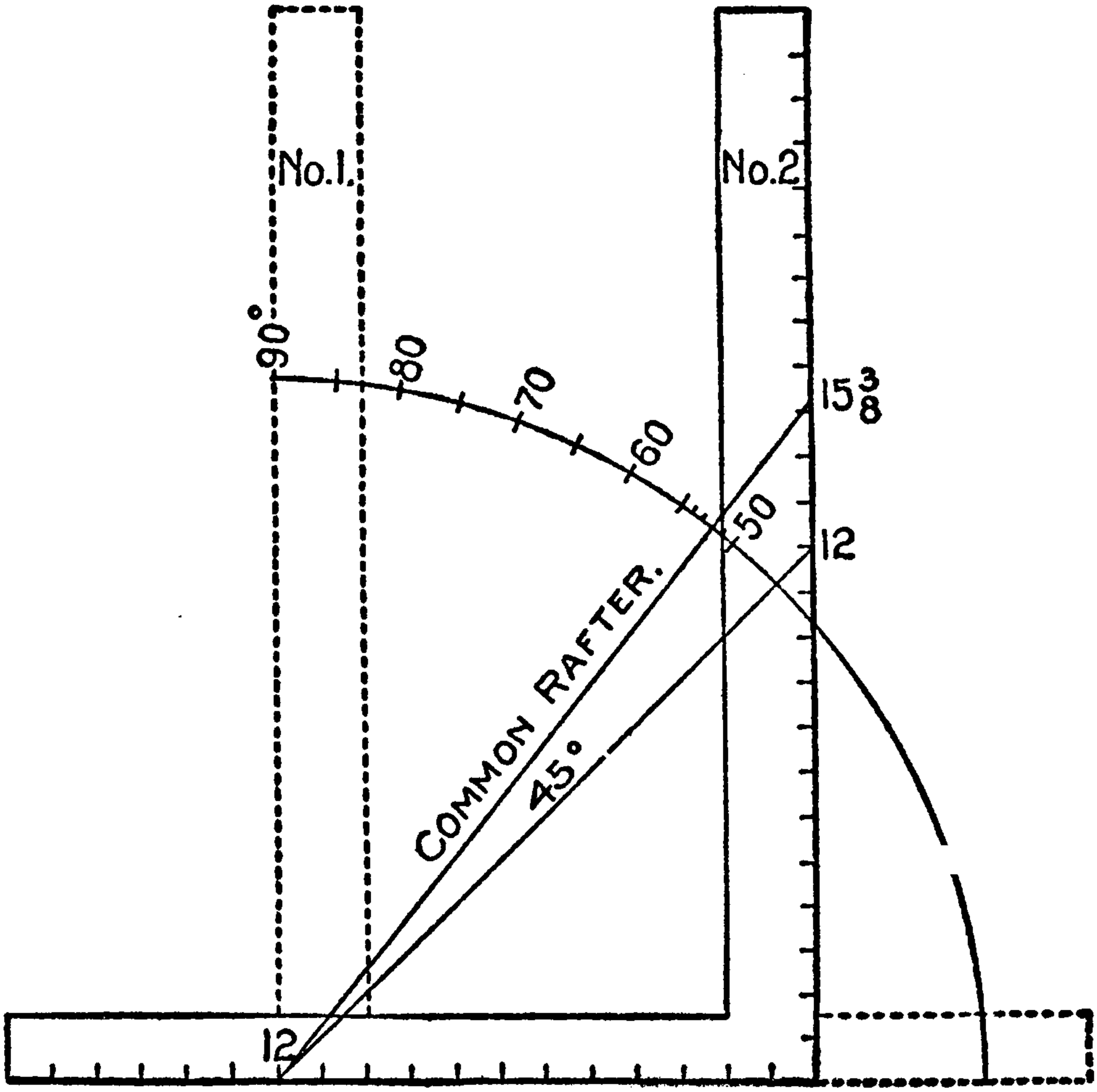

FIG. 50

equal parts will give the division of the degrees. However, it is only necessary to divide that section containing the desired degree. If it be 52 degrees then we divide the space above 50 degrees, as shown, and a line from 12 on the tongue and passing at 52 degrees will intersect the blade at $15\frac{3}{8}$ inches and represent the rise per foot in the run.

In Fig. 51 is shown a diagram of how to find the lengths of the rafters to a given scale, also

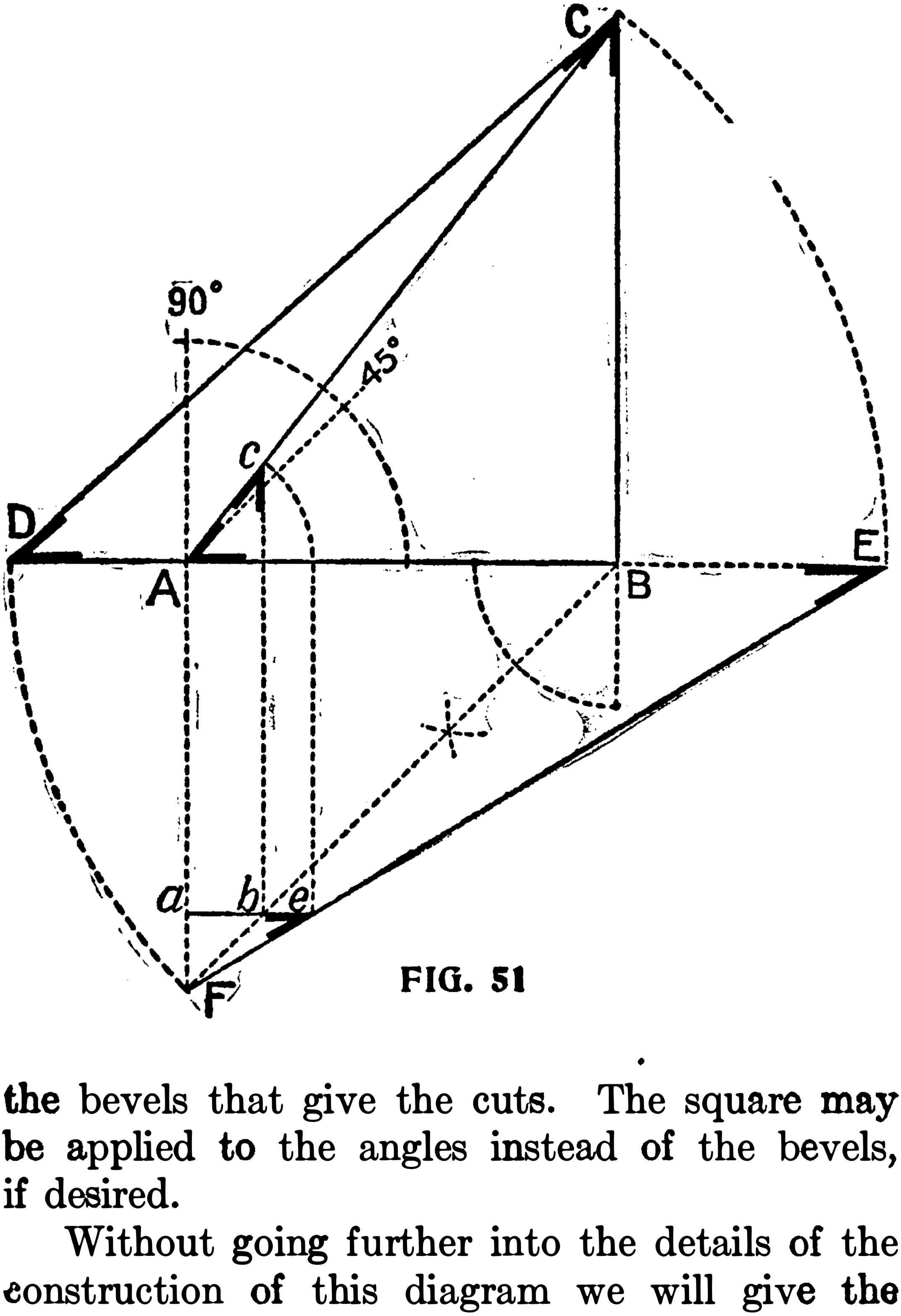

FIG. 51

the bevels that give the cuts. The square may be applied to the angles instead of the bevels, if desired.

Without going further into the details of the construction of this diagram we will give the different parts as follows:

Let AB represent the run or seat of the common rafter, and with A as center lay off the arc and proceed as in Fig. 50 for the pitch. BC will represent the rise, AC the length of the common rafter, BF the seat or run of the hip (this line always rests at an angle of 45 degrees with AB, unless the adjoining sides of the roof are of a different pitch), and equals DB. DC represents the length of the hip and equals FE, the latter being drawn to obtain the bevels for the cuts. AE is obtained by dropping AC on a line with AB.

a, b represents the run of the first jack from the corner, and by squaring up to AC, as shown, its length will be Ac, and represents the common difference in the lengths of the jacks. The seat and down bevels remain the same as for the common rafter, but require an additional bevel across the back to obtain the cut to fit against the hip. This is found by extending ab, intersecting FE, as shown, at e.

It will be seen that ae equals Ac, and may, therefore, be taken for the length of the jack.

For the backing of the hip, lay off one-half of its (the hip's) thickness from D on line DB (seat cut) will give the gauge line or the amount to remove to a center line at top of the hip.

Octagonal Roofs.—Fig. 52 represents an octagonal roof. In its construction the suggestions following, on octagons, must be referred to.

To find the side of an octagon when the side of the square is given. Multiply the side of the

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pair, measured square back from the down bevel. The third and fourth pairs are to be cut shorter than the first by half the diagonal of a square whose side is the thickness of the first rafters. If the thickness of the first pair is 2 inches, then the third and fourth pairs are shortened by 1 and 5-12, as 2 and 10-12 is the diagonal of a square whose side is 2.

The first and second pairs have no side bevels; the side bevels of the third and fourth run back on both sides from the middle of the rafter. Find this bevel by taking the original length of rafter on blade and its run on the tongue, when the blade shows the cut. The backing of the hips obtain by taking 5-12 of the rise on the tongue and the length of hip on blade, the latter giving the bevel; for the side of an octagon is 5-12 its square width.

Half the square width is the run of the middle jack rafter, from which and its rise we get its length. From the length deduct the same amount as from the third and fourth pairs of hips. If there are to be two jacks between the middle one and the corner, we divide the length of side into three parts, also the rise, whence are obtained as before the distance of rafters apart, and the rise of the shortest jack. Divide half the square width of octagon by three to find the run of shortest jack. Just as the square is laid on to find the length of a jack, it gives the down and lower end bevels; while the side bevel is obtained by taking length of middle jack

on blade and half one side of the octagon on the tongue; the blade giving the cut.

Lengths and Bevels of Hips and Jacks.—The following illustrations and reading matter are from Mr. Woods' pen and are largely self-explanatory. They show the lengths and bevels of hips and jacks for an octagonal tower roof. The seat and plumb cuts are found in the usual way of taking the proportion of the run and rise on the tongue and blade but there must be an additional or diagonal cut across the back of the jack to fit against the hip, as shown in Fig. 53 by the dotted lines at A-B. These lines are always vertical and the same distance apart regardless of the pitch

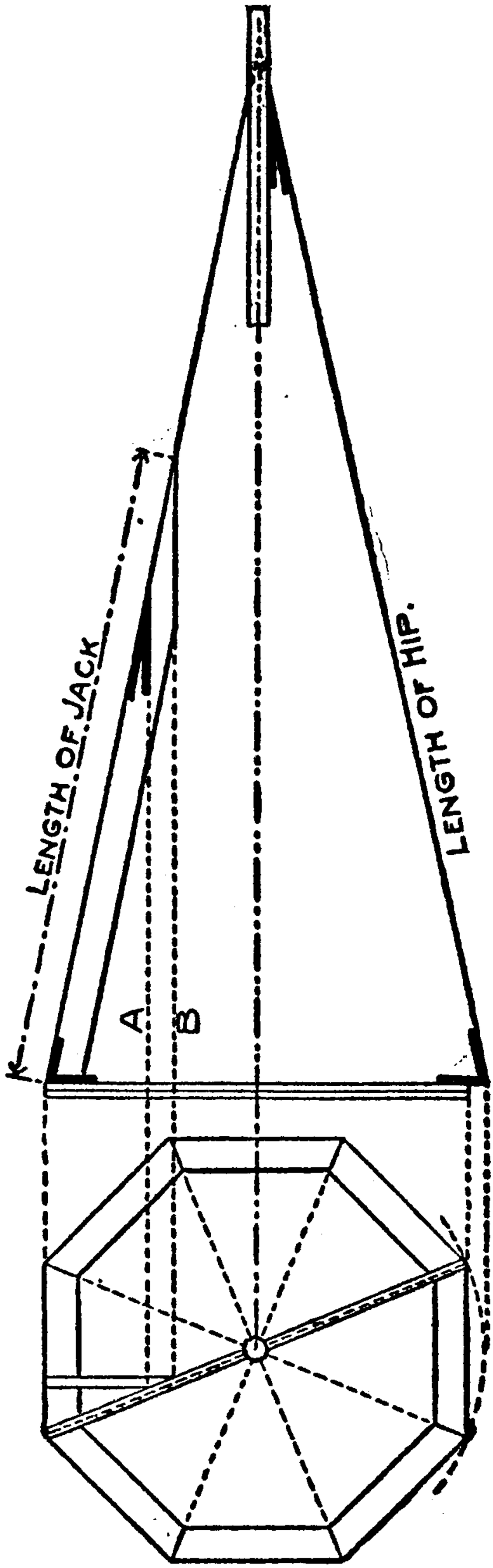

FIG. 53

given. A diagonal line from A to B across the back of the jack determines the angle.

Fig. 54 illustrates this point. If there were

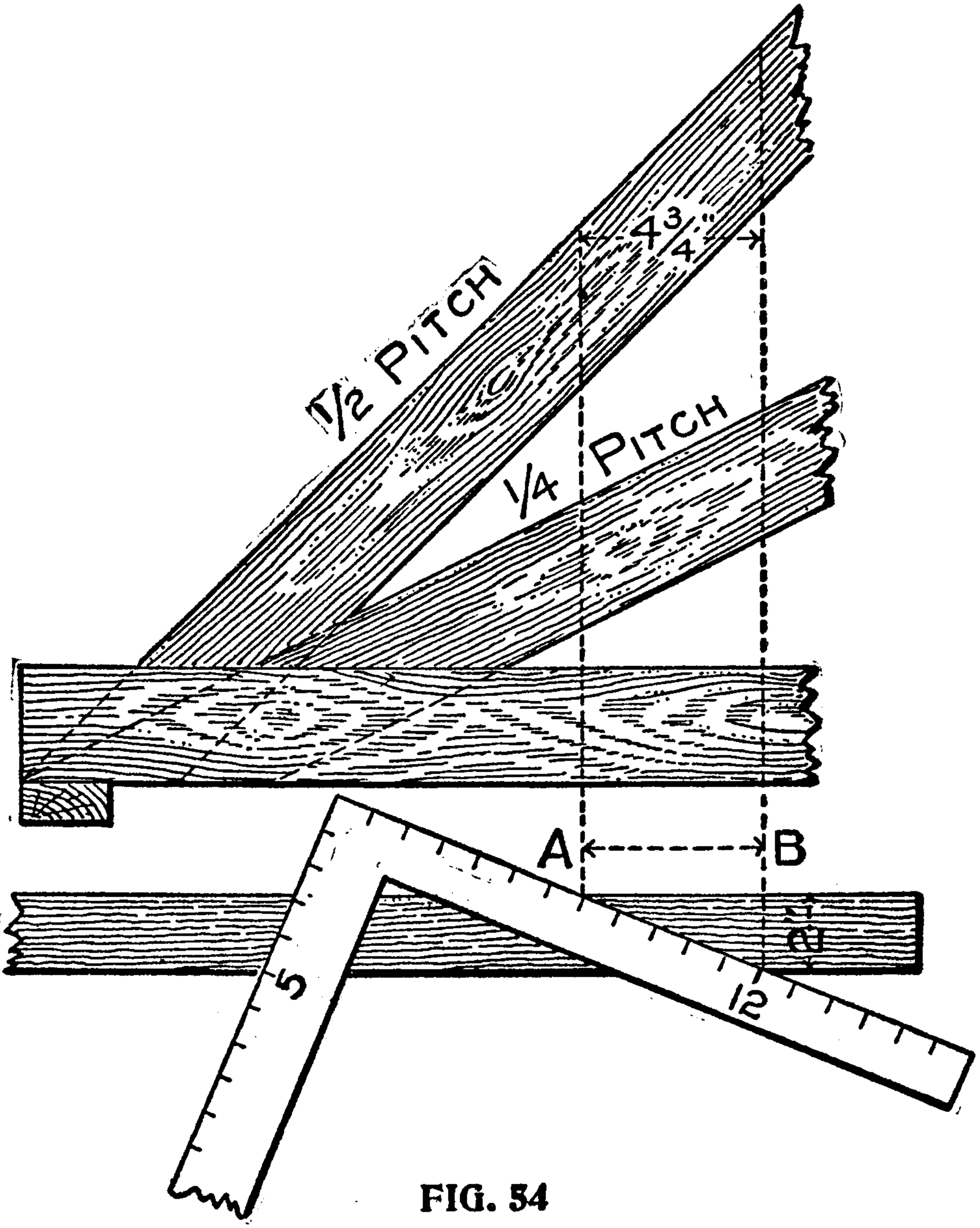

FIG. 54

no pitch at all then 5 and 12 would give the cut. These figures also give the starting lines A and B, which, since the rafters are of the same thick-

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elaborate diagram. A simple line drawing like that shown in Fig. 55 illustrates all that is contained in Fig. 53.

In the plan shown in Fig. 53 it will be seen that the hips do not come to a common center within themselves, but instead are resting against a center piece which may be a finial or flag pole, and in that case furnishes an excellent bracing for same, but when this is used the lengths of the hip must be shorter. The best way to obtain this is to find the full length of the hip and lay off the plumb cut and from this at right angles measure off one half the thickness of the pole, which will give the proper point of the plumb cut. When this pole is omitted the common way is to let one pair of the hips butt against each other as shown in Fig. 56. The runs are reckoned from the outer edge of the plates to the center, as GO for the common rafter and OF for the hip, but since all of the rafters do not run to the center there must necessarily be a deduction from the runs, as given above.

In the plan it will be seen that only one set of the hips (No. 1), meet at the center. Set No.2 lacks the thickness of No. 1 of coming together, or an amount equal to OA taken from the run of each rafter. The next two sets, No. 3, are of the same length, and the deduction for this is equal to OB plus BC to obtain the plumb cut for the side bevel . The run of the common rafter, No. 4, being GO the deduction from which is

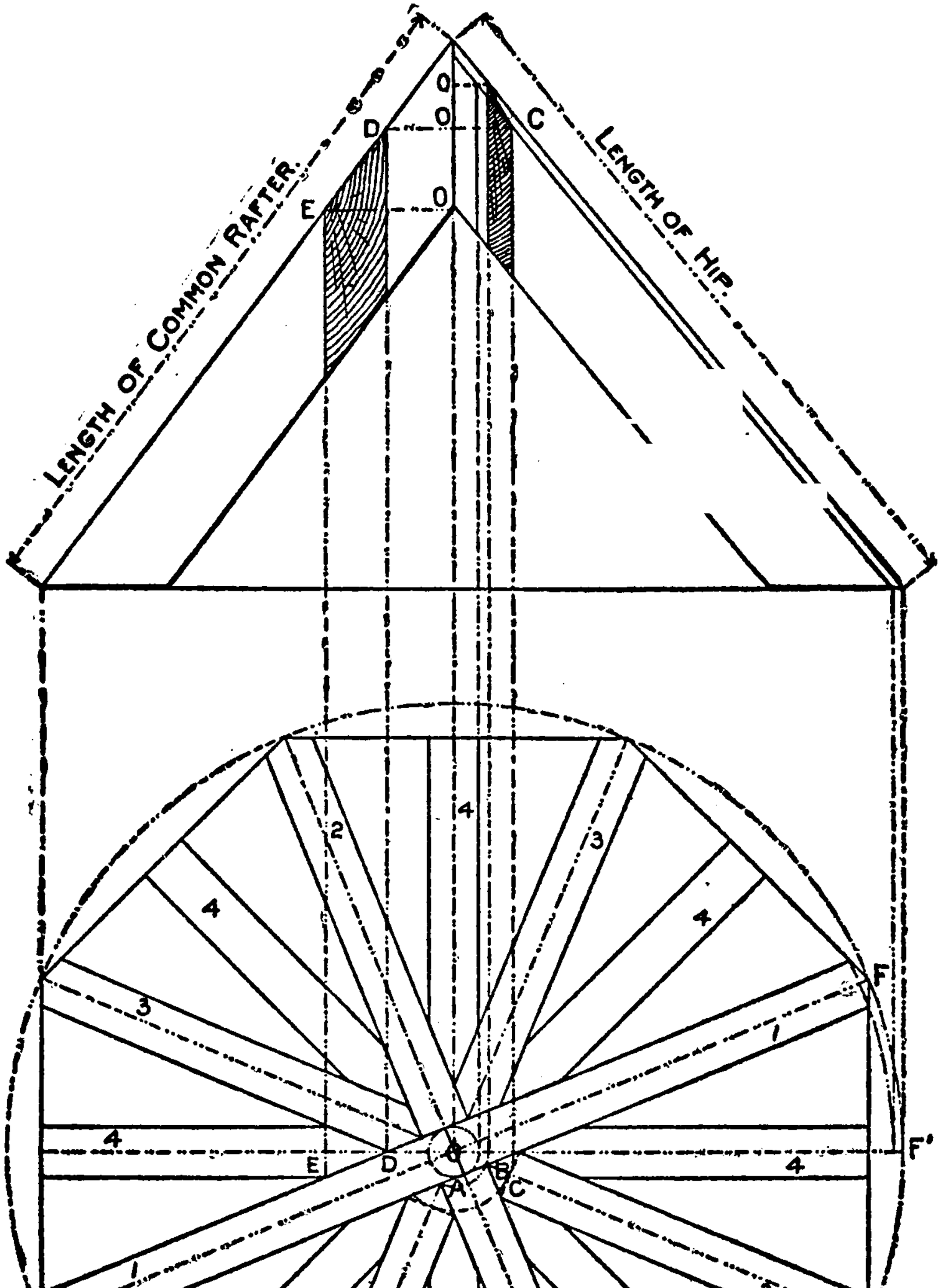

FIG. 56

equal to DO plus ED to obtain the plumb cut for the side bevel.

Now, referring to the elevation, the above reference letters are used for like measurements, showing the proper deductions to be made to obtain the lengths for the different rafters by simply squaring back the above amounts from the plumb cut for the full length rafter.

The run and rise taken on the square regulate the seat and plumb cuts, but the above deductions remain the same for any pitched roof.

To Obtain Length of Various Rafters for Any Width of Building.—In Fig. 49a, we gave an illustration showing the comparison of the runs of the octagon hip and for a hip resting on a square cornered building, to that for a one-foot run of the common rafter.

Now since these lengths taken diagonally from 12, 13 and 17 on the tongue to the figures designating the rise on the blade represent the lengths of the rafters for a one-foot run, it is an easy matter to find the lengths for any run by simply multiplying the lengths given by the number of feet and fraction of a foot in the run, and point off as many figures in the product as there are decimal figures in the solution and reduce to feet and inches. The finding of the length for a fractional part of a foot in the run may be avoided by finding the length only for the number of feet as described above and lay off a plumb cut, then from this measure square out the amount of the fraction, which will be the

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must be to the ratio of 13 and 17, as 6 is to 12 nches.

Therefore in this example, it would be $6\frac{1}{2}$ inches for the octagon hip and $8\frac{1}{2}$ inches for the hip, or valley, for the square cornered building.

In Fig. 56b are shown these proportions in connection with the steel square. The run of the hip for a square cornered building rests at 45 degrees from that of the common rafter and that for the octagon hip at $22\frac{1}{2}$ degrees. So then, we let the tongue of the square represent the run for the common rafter, and by laying off the diagonal lines to 5 and 12 (the figures that represent the degrees) on the blade, and by squaring up six inches to the right of the starting point (12 on the tongue) it will be seen the diagonal lines are cut at the center of their lengths.

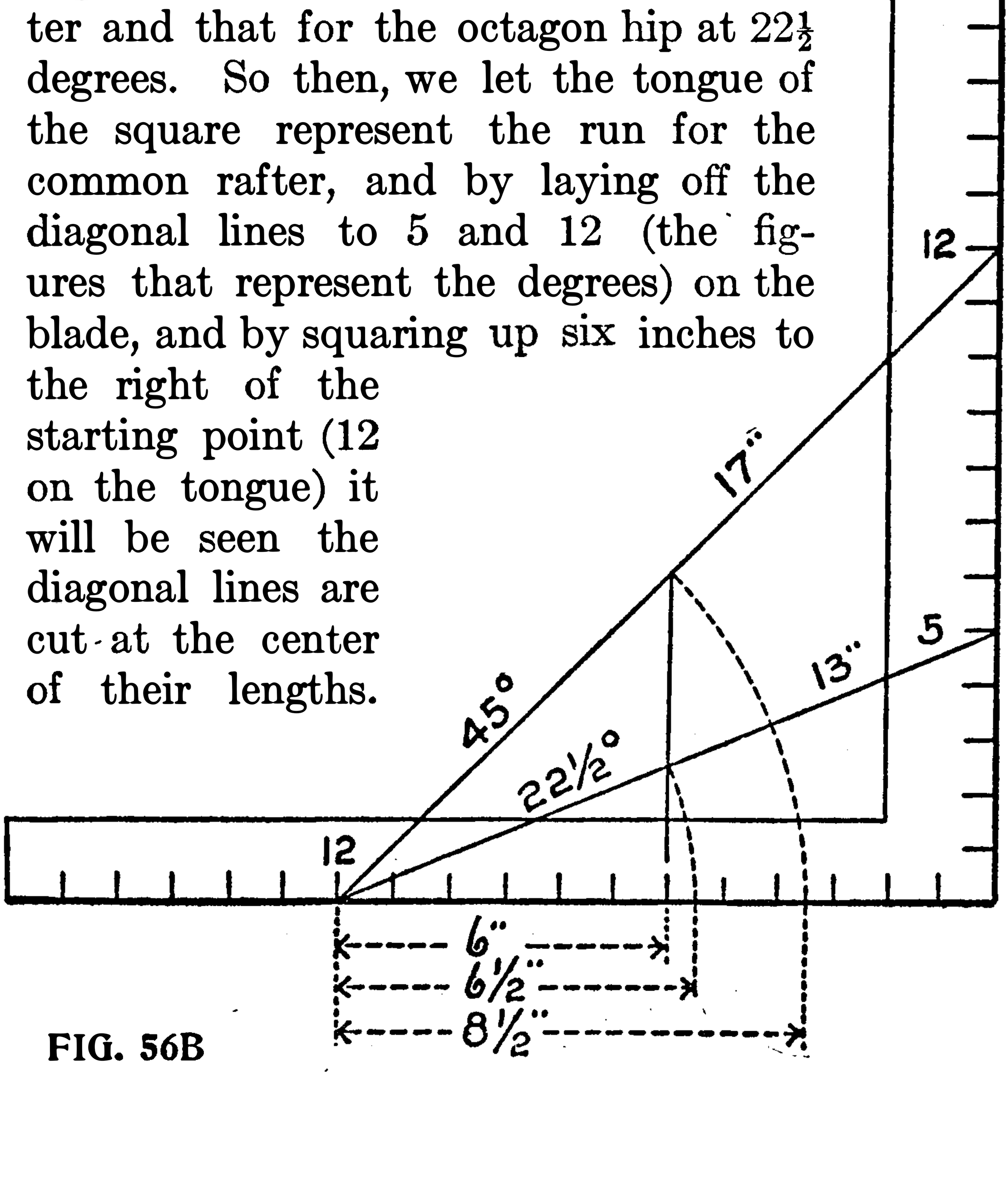
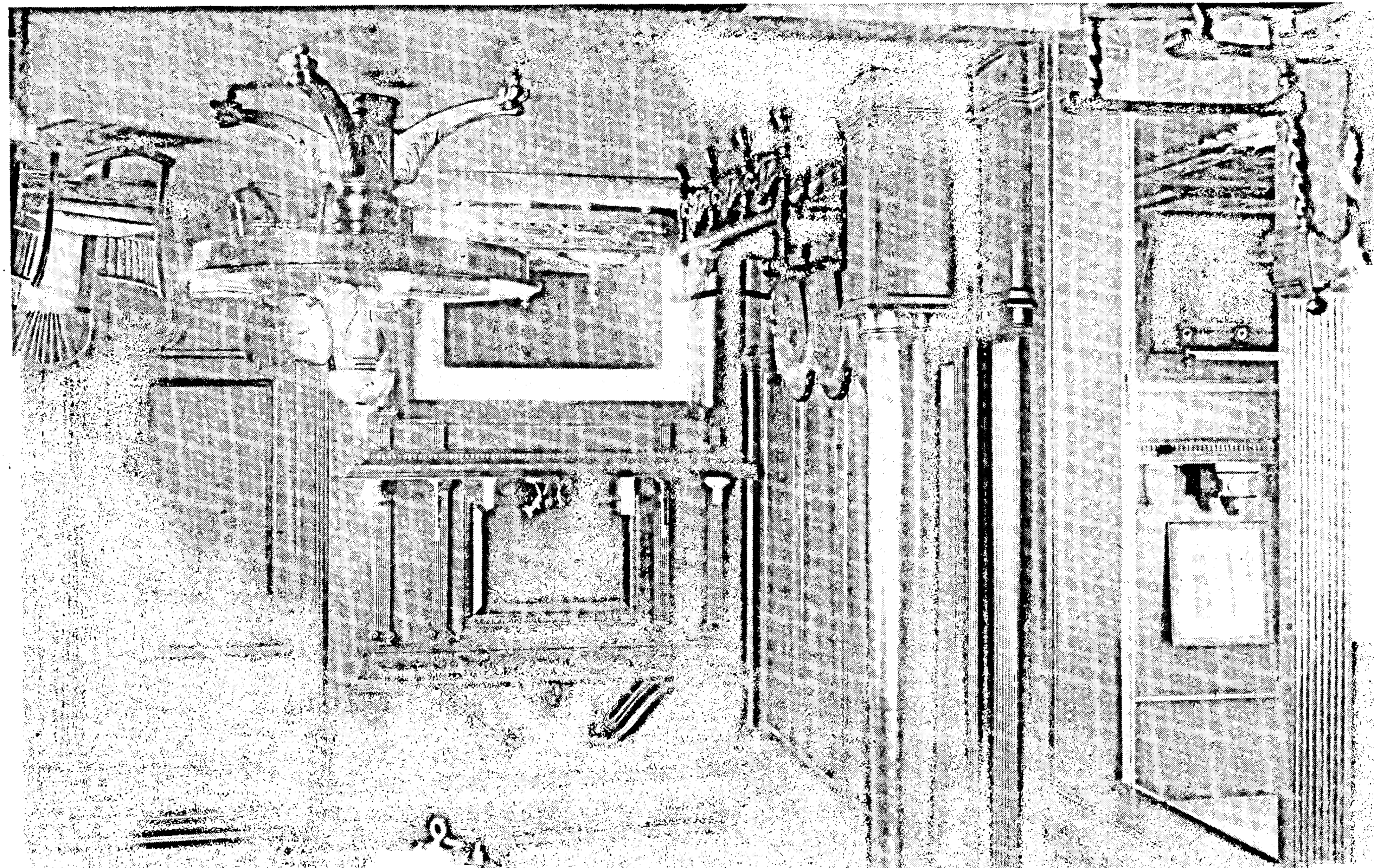


FIG. 56B



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rafters for one-inch run, as before mentioned, and in that case the lengths given above would be so many twelfths of an inch and the decimal fractions would only be fractions of a twelfth of an inch. Thus, to find the lengths of the hip for a 7-inch run, would be 19.21 x 7=134.47 twelfths inches, equal to 11 2-12 inches. The .47 is discarded because it is less than one-half of a twelfth of an inch. This also applies to finding the common difference in the length of jacks. Since a jack is simply a part of a common rafter, it is only necessary to multiply the length of the common rafter (15) by the number of inches in the spacing and divide by 12, will give the answer. Thus—if the jacks be placed 16 inches on centers 15 x 16=240÷12=20 inches, will be the length of the first jack or the common difference for a roof with a 9-inch rise. As this example is without fractions, we will give another, taking that for the 8-inch rise or 1-3 pitch. In this, the length of the common rafter is 14.42. Then 14.42 x 16=230.72÷12=19 2-12 inches, and is the answer. To find the common difference for the octagon jack for the above pitch, proceed in like manner, but multiply 14.42 by 2.4 and the product by the spacing and divide by 12 will give the answer. Thus 14.42 x 2.4=34.608 x 16=553.728÷12=46 1-12 inches. The decimal fractions in the two last examples are discarded for the same reason as before described. These lengths are calculated to a center line at the ridge and at the center of the back of the hip or valley.

Therefore, reductions should be made from the lengths here calculated by squaring back from the plumb cut one-half the thickness of the ridge board, which will give the point for the proper cut for the common rafters and jacks that fit against same. For the jacks that fit against a hip or valley for a square cornered building, deduct one-half the diagonal thickness of the hip it rests against, by measuring square back from the plumb cut. Rafters are usually about $1\frac{3}{4}$ inches thick, and the proper reduction in that case would be practically $1\frac{1}{4}$ inches. However, the jacks will fit just as well though they will be one-half of their thickness out of their regular spacing, or if the measurement line is taken on the long side of the jack, then they will be of the proper length without any reduction.

Different Kinds of Jacks Described.—There are several kinds of jacks and while we are at this point it might be well to describe them. They are known by the position they occupy as follows: A jack with the upper end resting against a hip is called a hip jack. A jack with the upper end against the ridge board and the lower end against the valley is called a valley jack.

A jack cut in between a hip and a valley is called a hip and valley jack, or more generally known as a cripple jack. The latter in many cases is a very appropriate name, however, we prefer to call them by the former name.

In Fig. 56c is shown a plan of these jacks.

The measurement line is at the center of the back in each case and shows all of them to be for the same length of run, the dotted lines showing the amount of the reduction to be made to fit to their proper place. In this, it will be seen that the cut across the back of the jacks(commonly called side cut) is at an angle of 45 degrees

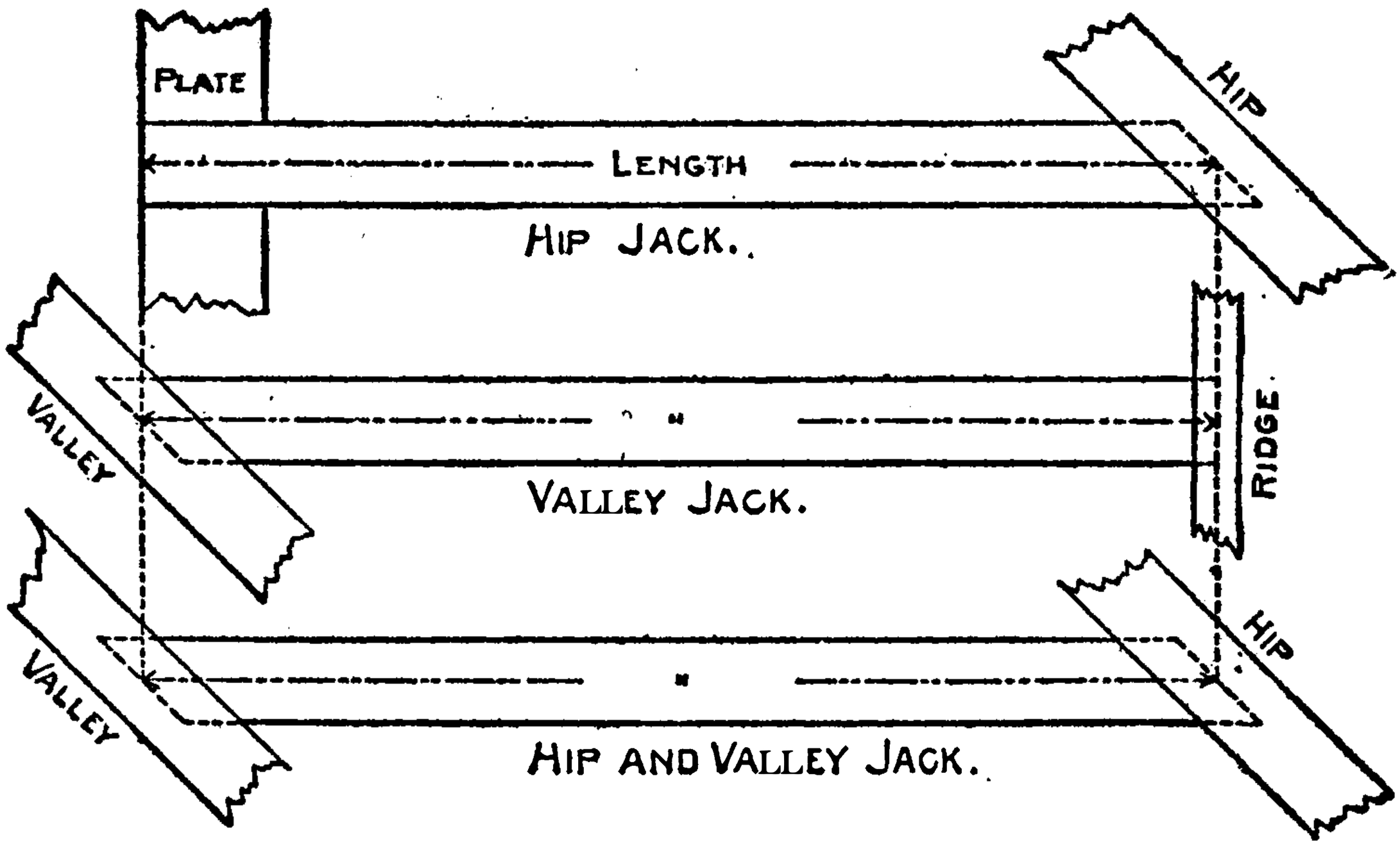

FIG. 56C

and this remains so regardless of the pitch given the roof. Therefore, the side cut of a jack, in one sense of the word, is a miter just the same as for a square-cornered frame. To prove this, after the side cut has been made for any pitch, cut off the peak end of the rafter on a line parallel with the seat cut and it will be seen that the angle is at 45 degrees, just the same as shown in the plan.

Hexagonal Roofs.—Take 6 and fifteen-sixteenths on the tongue and 12 inches on the blade,

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find this, take half the side of the hexagon on the tongue and half the square width added to the gain of the hip-rafter in running that distance, on the blade. The tongue gives the cut. Strike the bevel across the rafter. Now, the second and third pairs are to be measured back

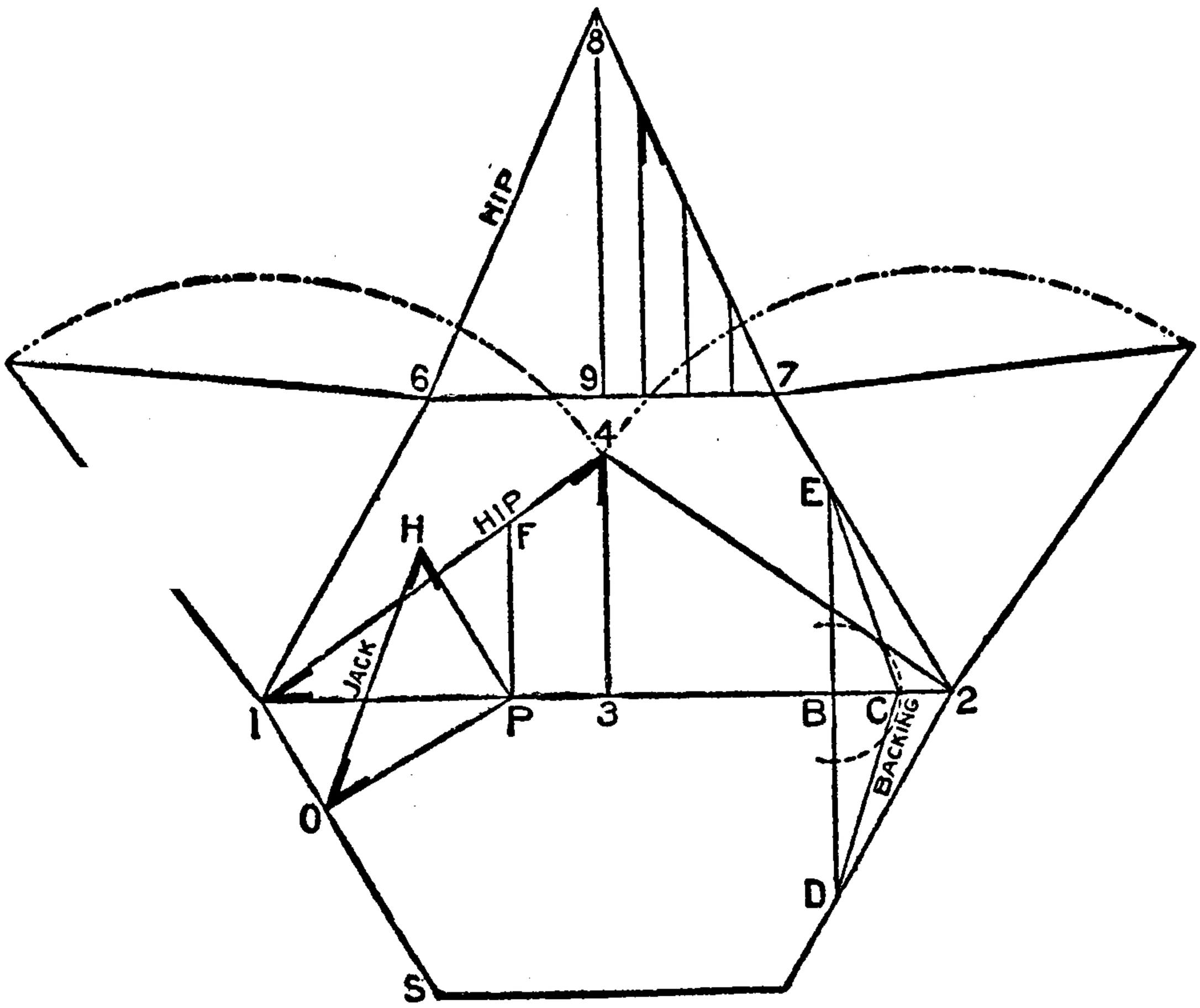

FIG. 58

shorter than the first pair, on their middle lines, just half the length of this bevel. The third pair has the bevel cut on both sides from the center. The backing of the hips is found by taking 7-12 the rise of roof on tongue and the length of hip on blade; the latter gives the cut. The side of the hexagon is 7-12 its square

width, or apothegm. The lengths and bevels of the jack-rafters are found as in octagonal roofs.

To Timber a Hexagon Roof.—On the line 1-2, Fig. 58, is the seat of the hips, 3-4 will be the rise. On the line 1-S say at O, draw a line at right angles touching the line 1-2 at P which is the seat of a jack rafter. From O-P at right angles draw P-H equal to P-F, and connect OH: this gives the length, seat and plumb cut of jack rafter. From 6-7 draw the line 8-9 indefinitely; set the compasses to 1-4, which is the length of the hip, and this length at 6 intersect 9-8 at 8, repeat from 7, which is the covering for one side of the roof, the intermediate lines being the lengths of jack rafters and bevels for side cut. On the line 1-2, say at B, take B for a center, touching the line 4-2, for radius, describe the arc BC; through B, at right angles to 1-2, draw the line DE, and from C to E and C to D will be found the bevels for backing the hips.

Hoppers and Hopper Bevels

In the laying out of many special types of buildings—such as farm buildings, or those intended for industrial uses, as mills, factories, shops, etc.—there are many problems of a special character constantly arising that call for ingenuity on the part of the carpenter. They do not necessarily involve new principles, but the application of familiar principles in new combinations or under new conditions.

Laying Out Hopper Bevels with the Square.—The subject of hopper bevels is one that is not generally understood among workmen. We have known good mechanics who could frame complicated hip and valley roofs, but when it came to laying out hopper bevels with the square, they were, so to speak, at sea. Yet the same principle involved in the framing of a hip-roof applies to a hopper—that is, a hip-roof inverted is a hopper. The roof boards that fit in the valley over the hip form the hopper joint. However, there are many ways of arriving at the cuts, and we will here present the views of various writers on the subject. Many have been published before, but we give them here because the progressive mechanic is not a "one way man," but wants to know the different ways of obtaining the same result, from which he can select the way that best suits his purpose. The following illustra-

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The following method of finding the bevels and width of sides and ends of a square hopper is from Mr. Connell.

In Fig. 65 the large square represents the upper edges of the hopper and the small one the lower edges or base. The width of the sides and ends is found in this way: Take the run ab on the tongue, and the perpendicular height ad on the blade. It is thus found in the same manner as the end of a brace. To find the cut for a butt

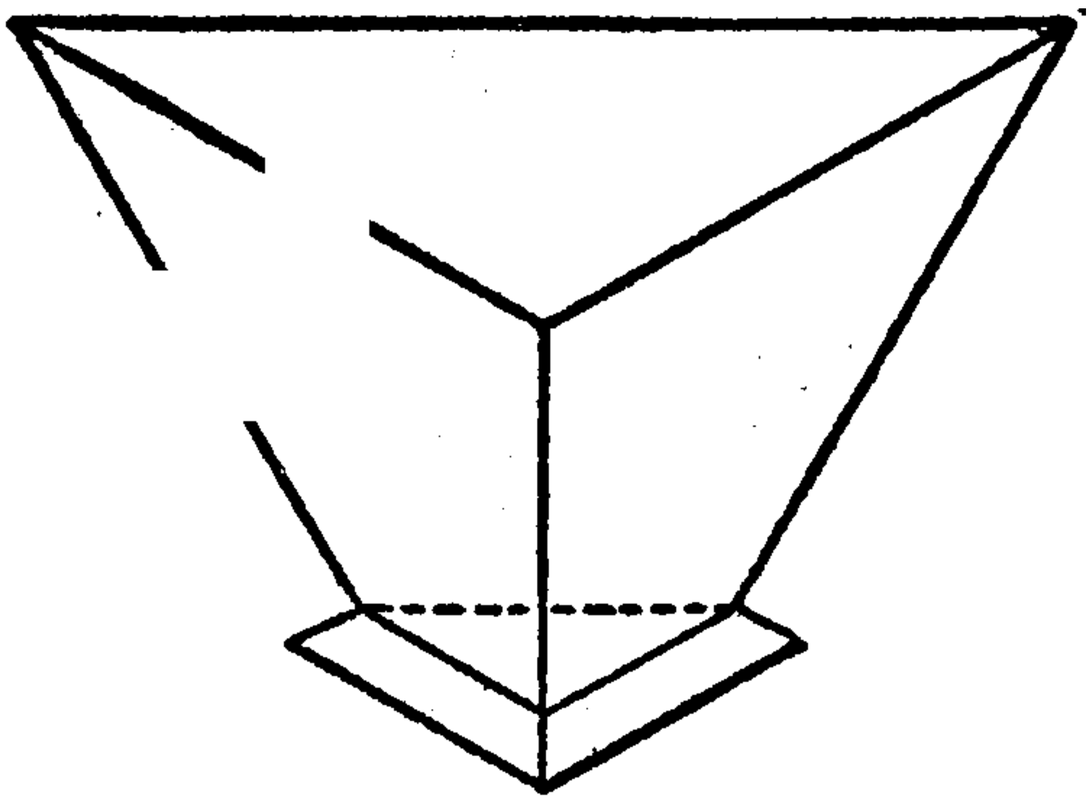

FIG. 63

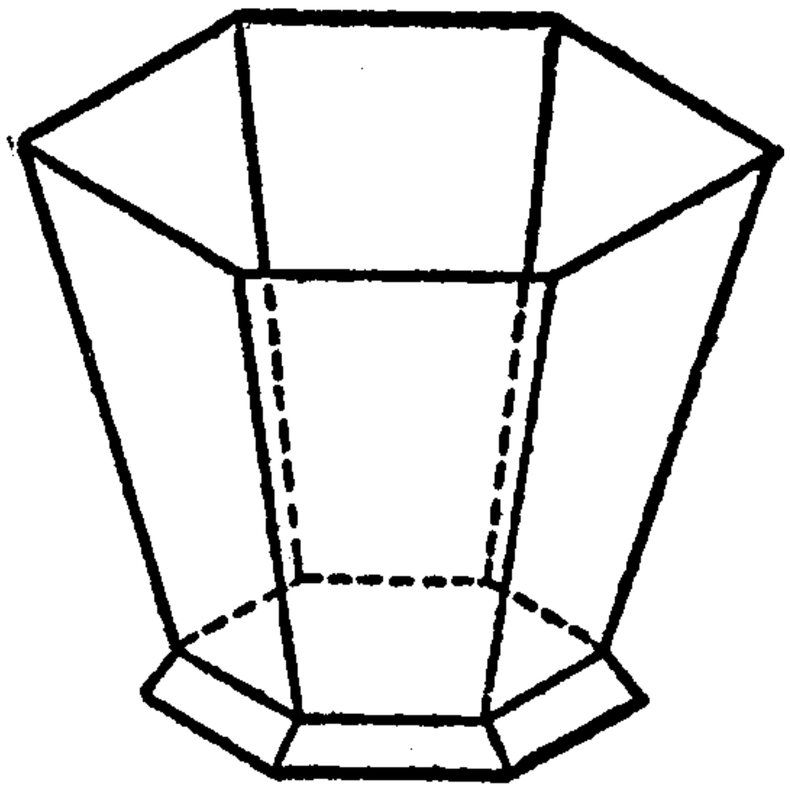

FIG. 64

joint, take the width of side on blade and half the length of the base on tongue; the latter gives the cut. For a miter joint take width of side on the blade and perpendicular height on tongue; the latter gives the cut.

For the cut across the sides of the boards, take the run ab on the tongue, and the width of side on blade; the tongue gives the cut. In case of butt joints the inside corners of the sides and ends are longer than the outside, so if a hopper is to be of a certain size, the lengths of ends and sides are to be measured on the inside

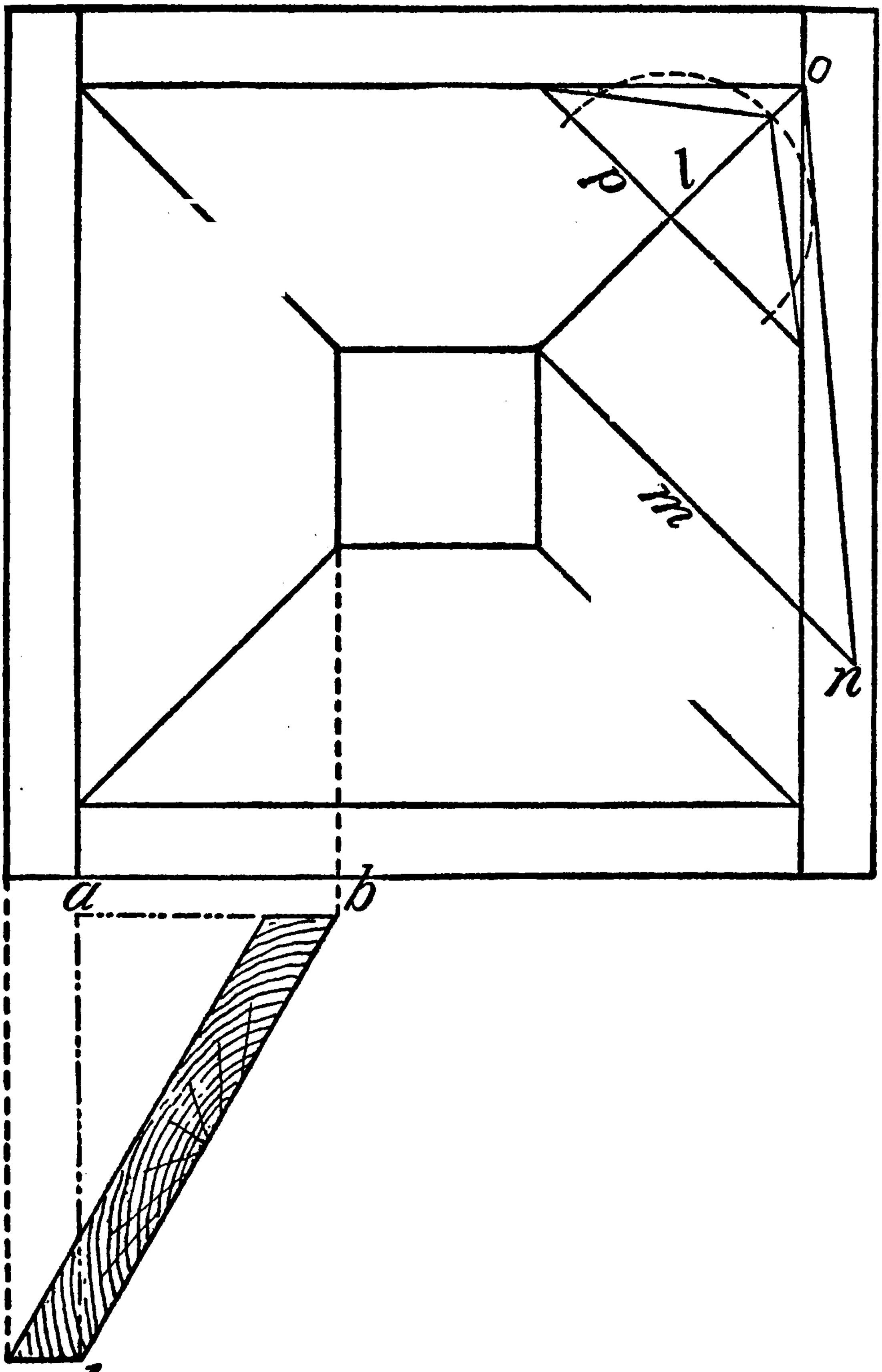

FIG. 65

edge of each piece, and the bevels struck across the edges to these marks. Of course if the hopper is to be square, the thickness of the sides must be taken from the ends.

If the top and bottom edges are to be horizontal, the bevel is thus found: Take the perpendicular height of hoppers on the blade and the run on the tongue, the latter gives the miter cut, in other words it is the 45 degree angle.

In large hoppers, pieces are put down along the corners to strengthen them. The length,and the bevel to fit the corner are thus found: Suppose the top of hopper is 8 feet, and the bottom 18 inches square. Find the diagonals of each, subtract the one from the other, and half the remainder is the run for the corner piece. From the length of this run, L, and the rise, ad, we find the length of the corner piece. To find the bevel or backing, take on the blade the length of the corner piece and on the tongue the rise; the latter gives the bevel. Another method is to draw the line, L, to represent the seat of the corner piece, set off square with this the line m, of the same length as the rise, ad. Then draw n-o, which is the length of the corner piece. To find the backing, draw a line, p, anywhere across L, strike a circle tangent to n-o. From the point of intersection of the circle with L, draw lines to the extremities of p. The angle made by these lines is the bevel or backing. From this it can be readily seen that the principles involved

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NS as radius describe the arc SU, intersecting the line NU in the point U. At S erect the perpendicular ST, and draw the line UT at right angles to NU. Connect N and T; then the triangle MNT is the end bevel required. The line NT is

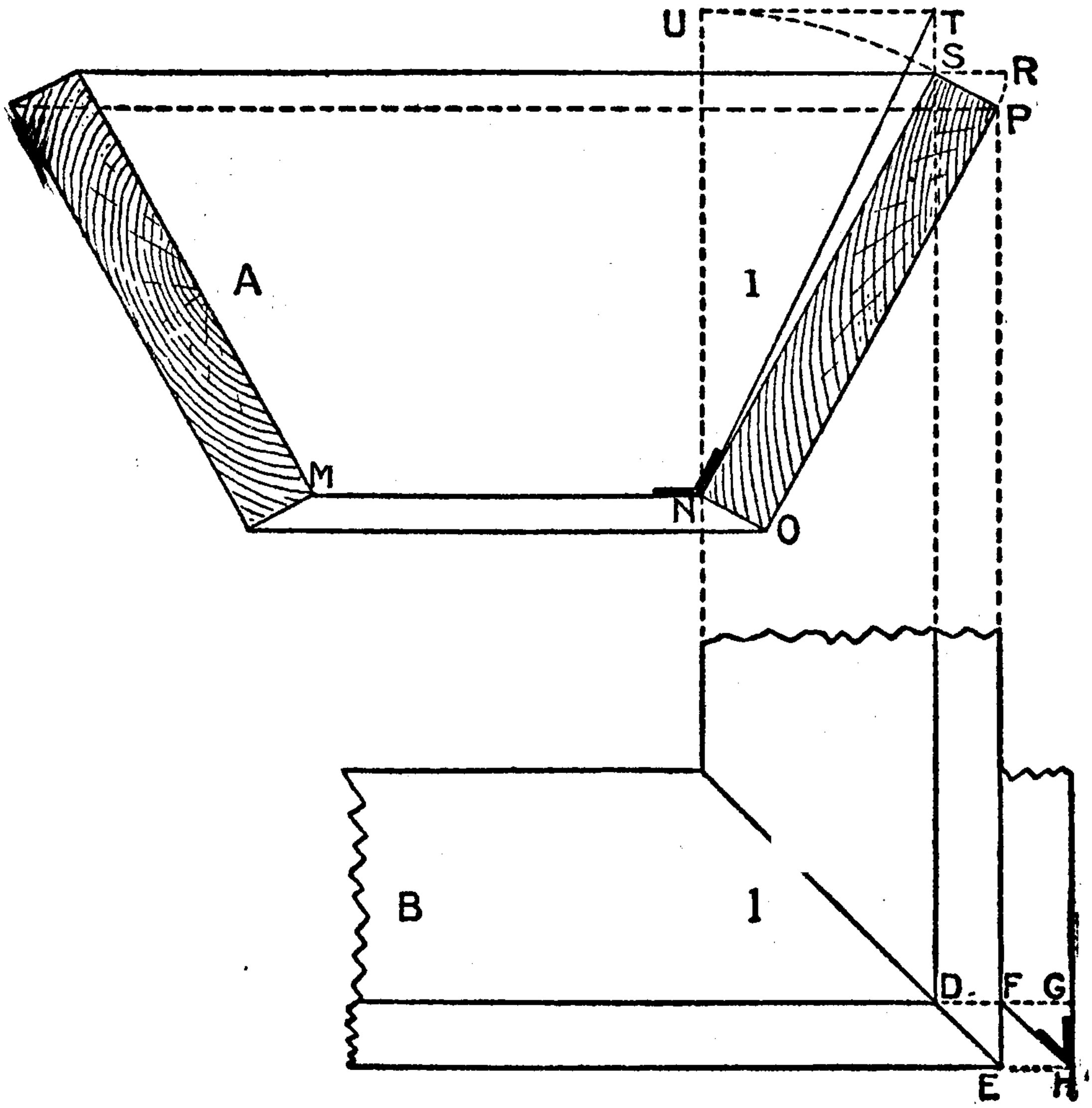

FIG. 66

the hypothenuse of a right-angled triangle, of which NU may be taken for the perpendicular and UT for the base. To find the miter of which DE is the plan, project S and P, as indicated in the plan by full lines. With SP as radius and

S as center, describe the arc PR. In the plan draw DG, on which lay off the distance SR, measuring from F, as shown by FG. Then GHF is the miter sought.

Fig. 67 shows the rule for finding the bevels

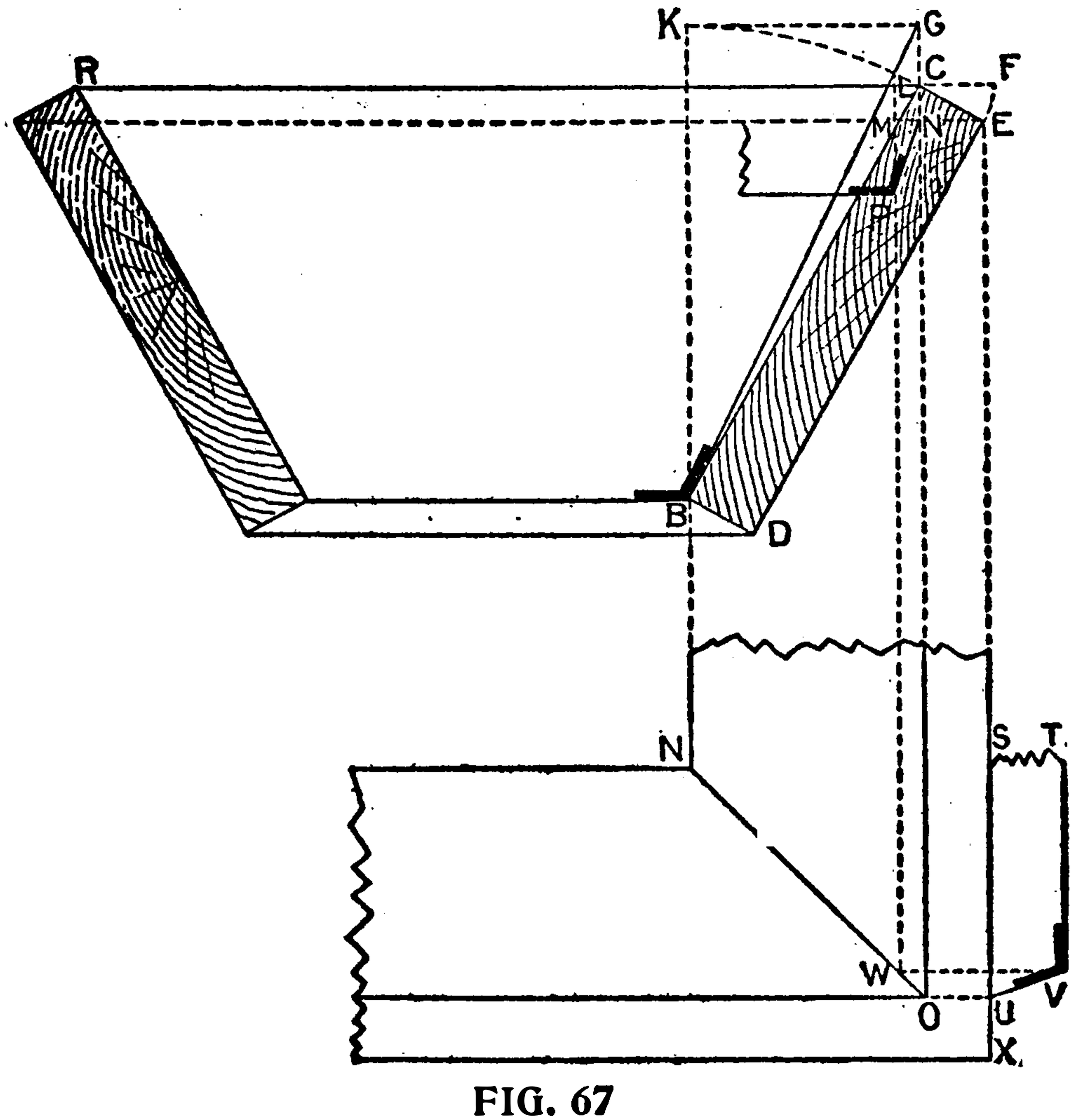

FIG. 67

for the butt joint of the hopper. From M, the point at which EM intersects BC, or the inner face of the hopper, erect the perpendicular ML, intersecting RF, or the upper edge of the hopper, in the point L. Then LC shows how much longer

the inside edge is required to be than the outside. In the plan draw TV parallel to SX, making the distance between the two lines equal to CF of the elevation, or, equal to the thickness of one side. From the point L in the elevation drop the line LW, producing it until it cuts the miter line NO, as shown at W. From W, at right angles to LW, erect a perpendicular WV, meeting the line TV in the point V. Connect V and U; then TVU will be the angle sought. This bevel may be found at once by laying off the thickness of the side from the line EM, as shown by NP

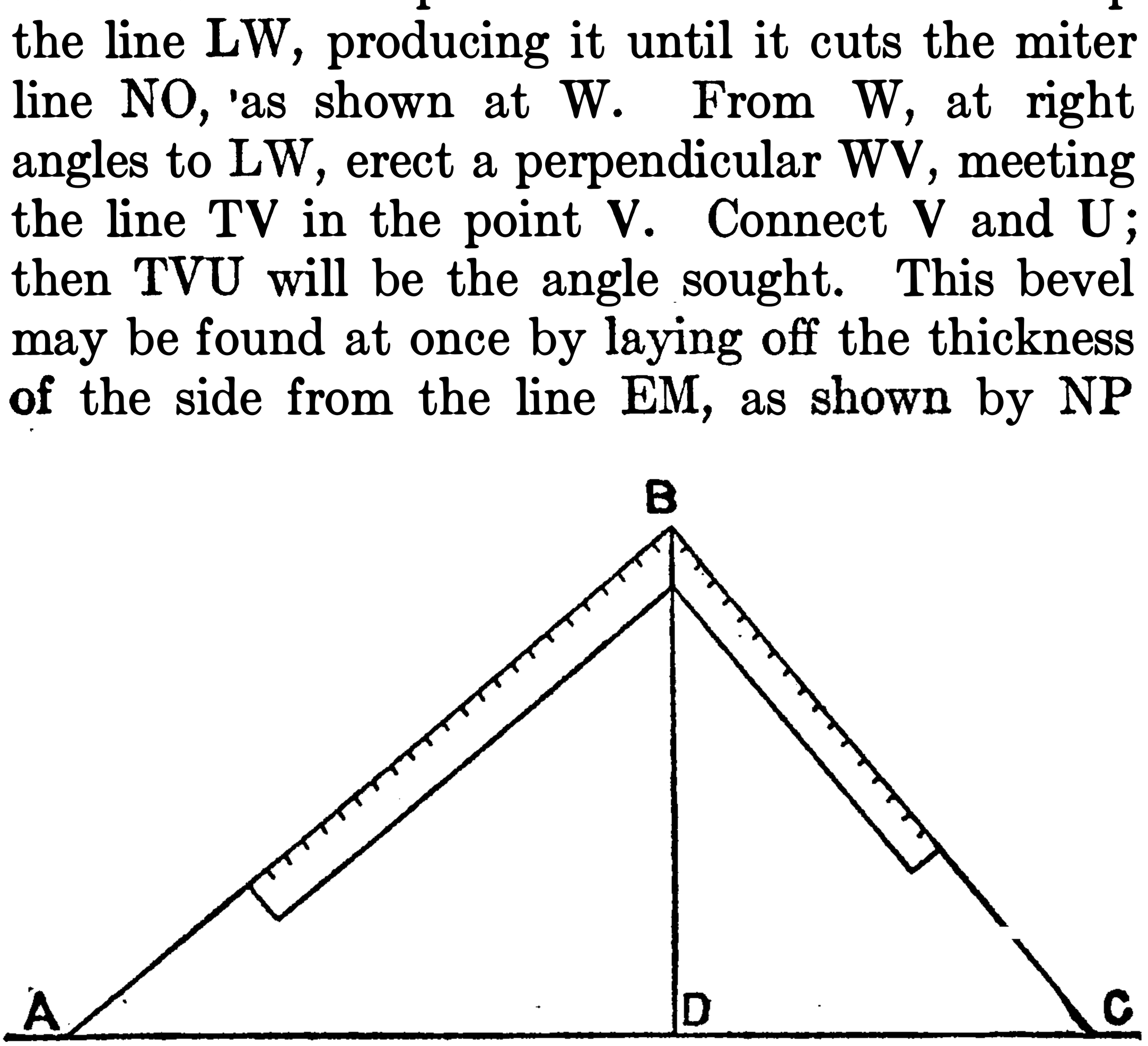

FIG. 68

in the elevation, and applying the bevel as shown. This course does away with the plan entirely, provided both sides have the same inclinaton.

There are several other ways by which the same results may be obtained, and some of these will no doubt occur to the reader when laying out the lines as shown here.

In Fig. 68 is shown another method for finding

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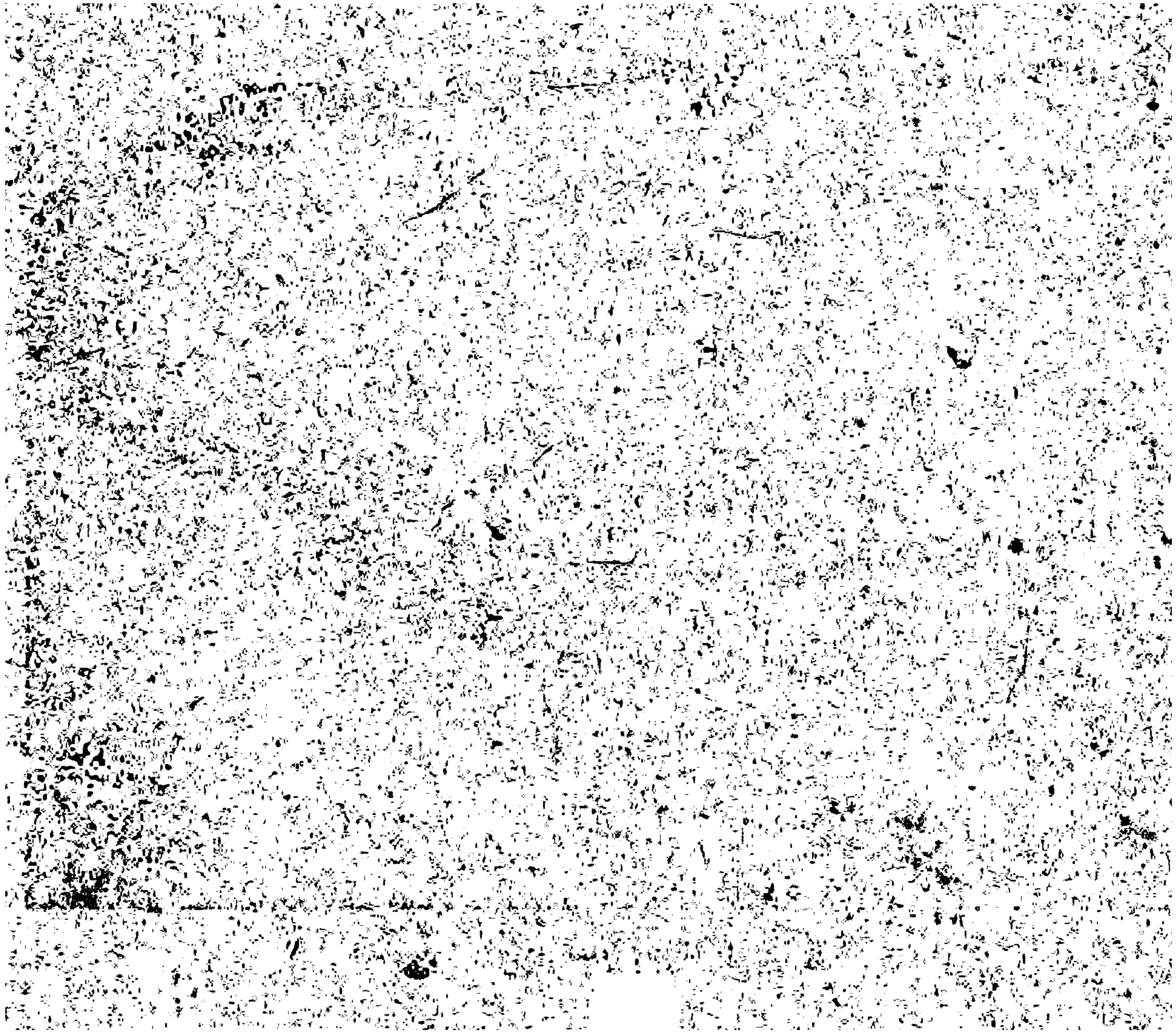

the bevels for a square or rectangular hopper. Let AB always be the guiding line, and the one from which all the others take their positions, making that line equal in length the width of the side of the intended hopper.

To find bevel to cut across face of board: Take AB on blade and AD on tongue; bevel of tongue is the line required.

To find miter: Take AB on blade and BD on tongue, line of tongue is bevel sought.

For butt joint: Take BC on blade and AD on tongue, and line of tongue gives bevel required.

Cuts and Bevels for Flaring Hopper.—In order to make this department complete, we herewith give a method by which the cuts or bevels may be obtained for a flaring hopper having only three sides. In other words, Fig. 69 gives bevels for a box whose top and bottom form two unequal equilateral triangles: Make the triangle CEF, then from the middle point of EF let fall the perpendicular BD, then draw AB parallel and equal to CD, also AC parallel and equal to BD, thus forming the rectangle A, B, C, D. Now draw CH to the same inclination from CD, that a side of the box when finished will show from the perpendicular line; then draw LD perpendicular to CH, and, with C as a center and a radius CL, make an intersection at I, and connect I and A, and at A is the bevel for the miter at the ends. Again with D for a center and a radius DL, make an intersection at K, and connect K

and B; and at B is the bevel for the down or cross cut.

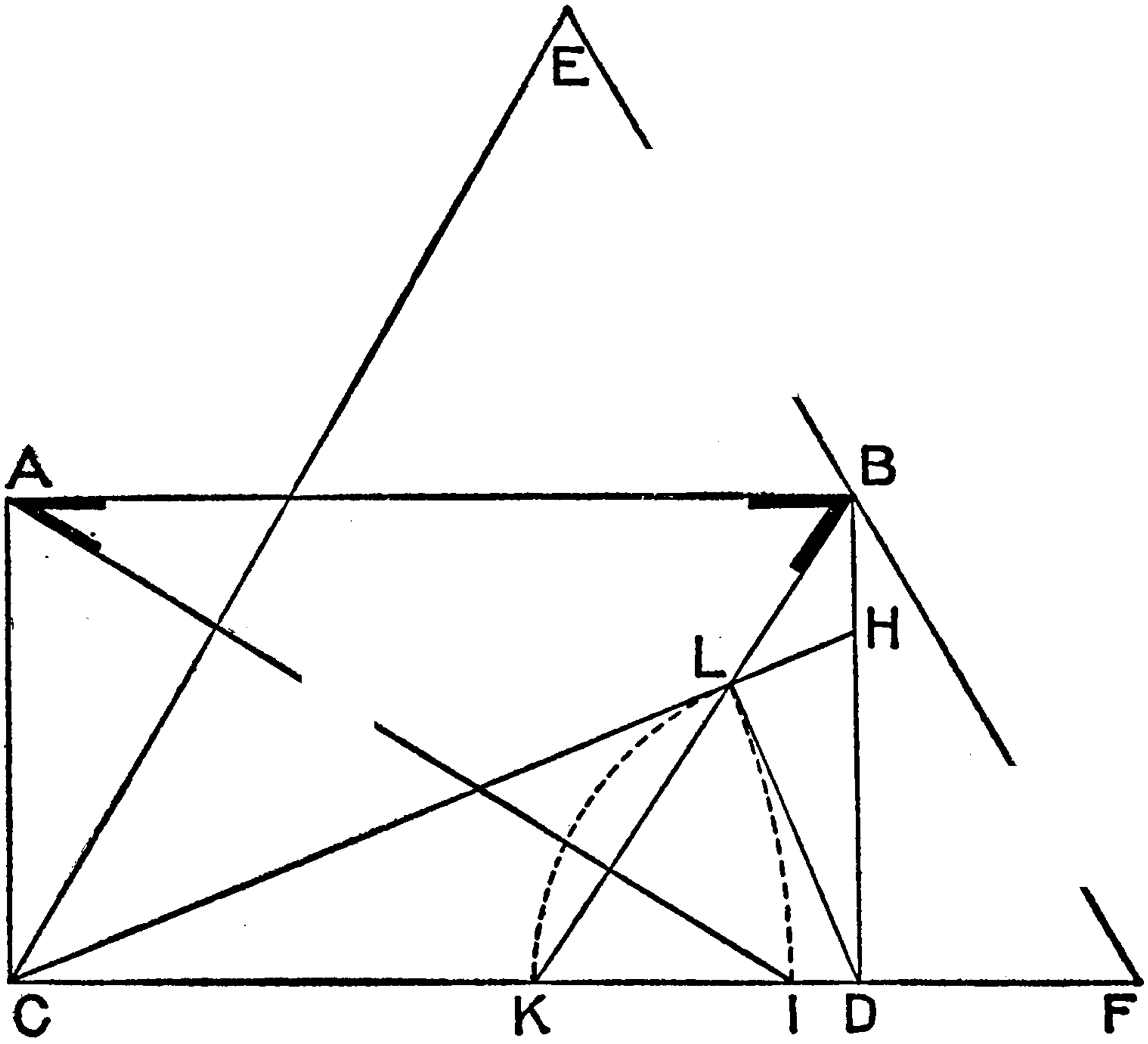

FIG. 69

To Find the Bevels Required to Miter Together the Flared Sides of a Hexagonal Hopper.—In Fig. 70, let NE be in the plane of the bottom of the hopper, and EJ the inclination of the sides; continue GD to B indefinitely; through J draw JO parallel to QD; through O draw AC at right angles to JO; make EM equal EJ; through M draw LC parallel to QD; make FH equal FJ; draw HA parallel to QD; through F draw FB

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applied to other figures, such as pentagons, octagons, or other similar hoppers, where the flares are equal.

Angles and Bevels for Hopper Work.—Sometimes the student may get in a little maze when working out the angles and bevels for hopper work, as the operation is often perplexing, and like the rules for stair-building, which will come a little later, requires patience and steadiness. There is no reason, however, because of these matters appearing difficult at first, that they should not be thoroughly understood by any ordinary workman, after two or three trials.

The following is from an article by Mr. A. W. Woods, published in a trade paper a short time ago:

Hopper Cuts are similar to the cuts required for fitting boards in or over a valley or hip roof; consequently the figures on the square that give the cuts for the roof boards must give the cut for a hopper of the same pitch.

Fig. 71 shows a hopper in different views, as follows: Beginning at the top is the top view of the hopper. As far as this part is concerned all hoppers are alike, as there is nothing in this to distinguish the pitch. Next is the sectional or side view. In this is shown the thickness of the boards and the flare or pitch, which in this is the three-quarters pitch. Next is shown the four sides in the collapsible or ready to be put together, followed with the top view of the edge of the board.

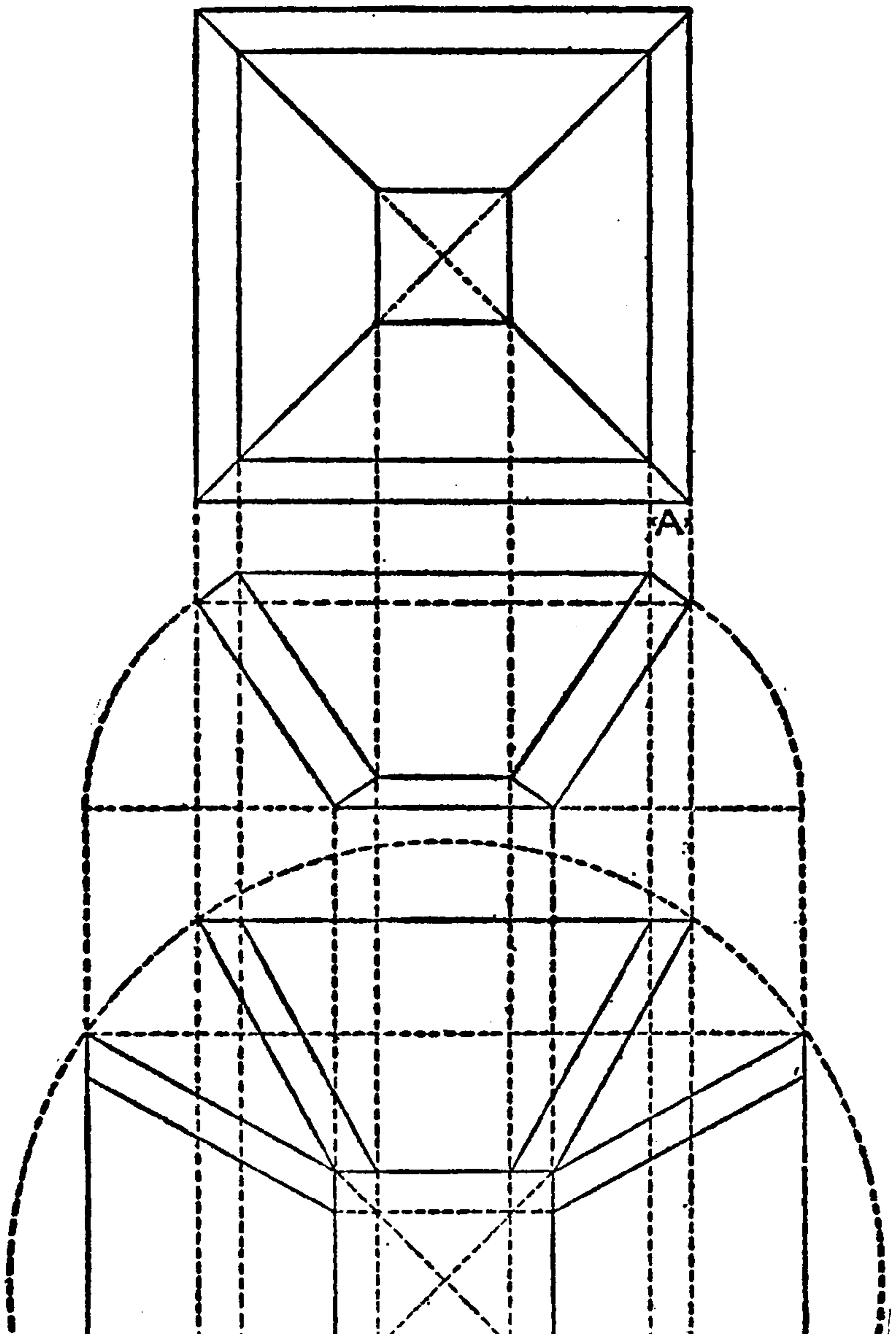

FIG. 71

Of course it is not necessary to lay out all of this diagram, or any of it for that matter; it is done by way of illustration. See the application of the square, which, in this case, is 12 and 21 and five-eights. But why use these numbers? Because the flare given is the three-quarters pitch or 12 and 18 on the square, and the hypothenuse of these numbers is 21 and five-eights, the tongue giving the side bevel. When working full scale it is always 12 on the tongue.

Miters.—For the miter bevel, the top edges should be first beveled so as to be level when in position. The miter would be at an angle

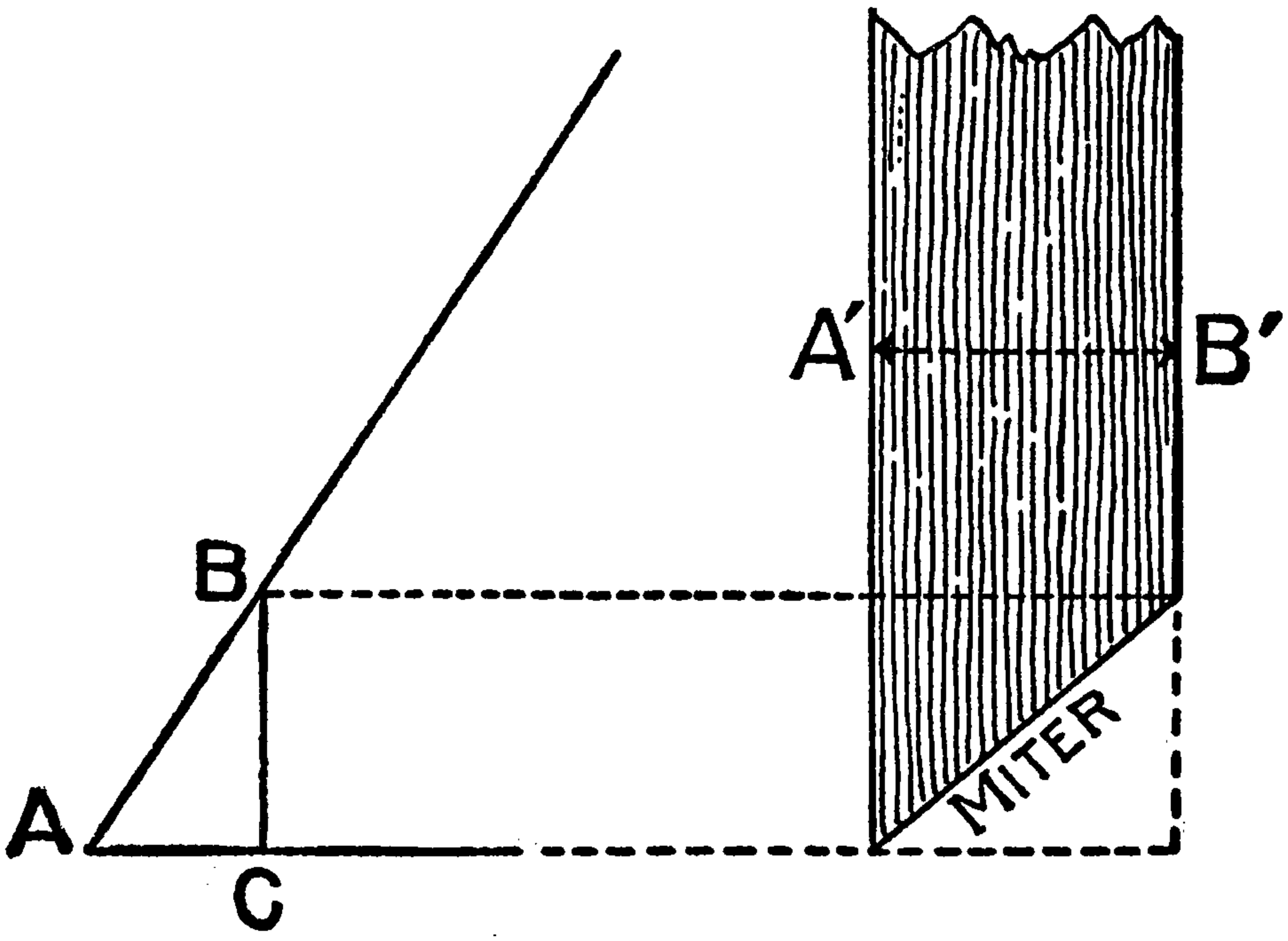

FIG. 72

of 45 degrees, and any of the equal numbers on the square gives this cut; but if the edges are to be left square with the sides, as shown, the above

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is better to use the one-inch scale as illustrated in Fig. 73. For example, let 7 feet 6 inches be the run and 16 feet and 3 inches be the rise. Take 7½ on the tongue and 17 and seven-eighths on the blade; the tongue gives the cut across the face of the board. Take 17 and seven-eighths on the tongue and 16 and three-twelfths on the blade and the tongue gives the cut across the edge of the board to form the miter, or it may be found by diagram as shown in the section.

Methods of Finding the Miter.—Great as the steel square may be in the hands of the learned mechanic, it is only secondary to the compasses. It simply steps in as an aid in defining what has already been determined by the compasses and their divisions called degrees. Therefore, we cannot pass the compasses by and the part they play without giving them due credit.

It will be our aim as far as possible to illustrate the part each instrument plays, thereby helping the student to more readily grasp the subject.

The old time masters, who set the recognized standard in architectural proportion, based their calculations upon the diameter of the circle and its divisions. Miters are governed by the divisions of the circumference of the circle, and not alone by the figures on the square. Therefore, to unlock the great fund of information contained in the arms of the square, it must be done by degrees. There are 360 contained in the circumference of the circle, and any of the regular polygonal miters can be readily found by dividing 360 by the num-

ber of sides in the polygon, and the quotient will be the angle that the miters stand with each other, but in order to obtain the angle with the steel square it is only necessary to take one-half of the degrees contained in the circle, or 180, and this divided by the number of sides in the polygon will give the degrees to use on the square. The reader will notice that we use 12 on the tongue for all miters; the reason we do this is because

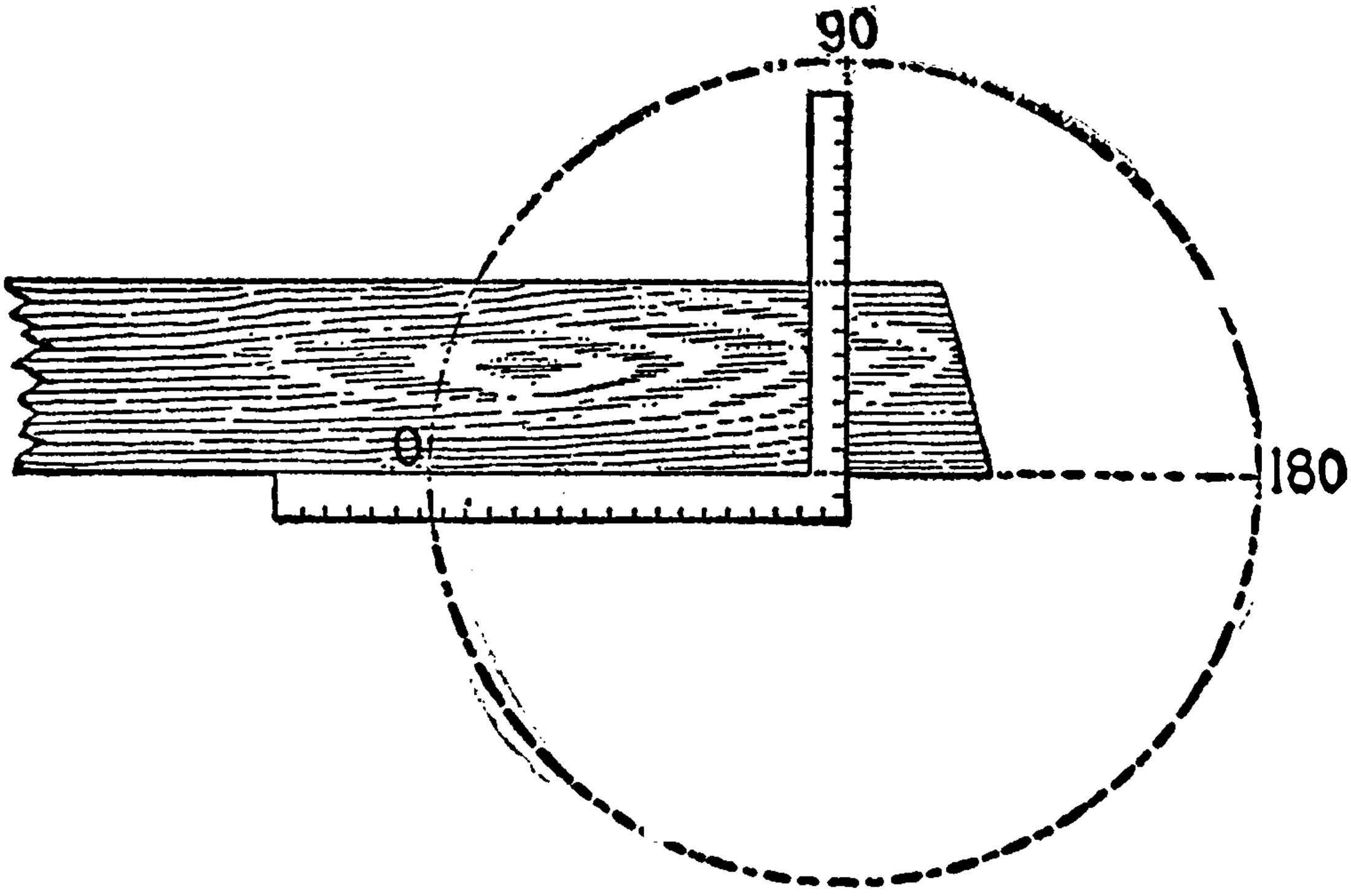

FIG. 73A

12 represents unity. It may represent one inch, one foot, one yard, or any other scale of measurement.

The casual observer sees nothing in the square beyond a simple measuring tool, or for squaring off the end of a board, which is the simplest of all the movements of the square. Yet as simple

as it is, it is governed by the degrees, as will be shown in referring to Fig. 73a.

In all cases a straight line, which may be the edge of a timber, represents one side of an angle from which the other side of the desired angle is reckoned, and in reality represents 180 degrees. Now, since the arms of the square set at an angle of 90 degrees with each other, just that much will it take from 180 degrees having the angle stand at 90 degrees as shown.

In Fig. 73b is shown the simplest of all miters, and it is used more than all others. The knowing

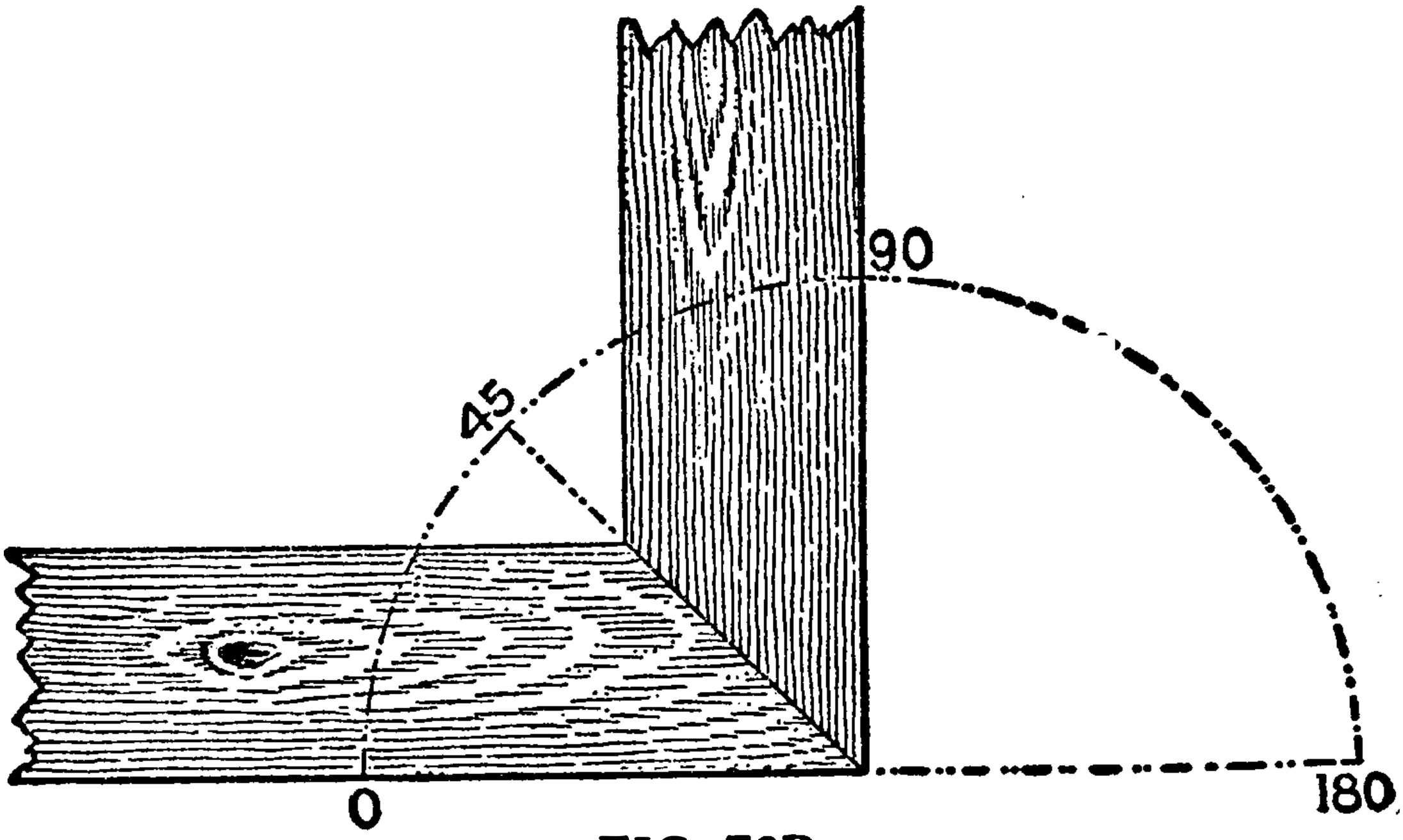

FIG. 73B

ones give the definition of the word miter as, "Joining two timbers at an angle of 45 degrees," without reference to any other angle. This is contrary to general belief and we see no reason why it does not apply equally as well to any other angle, and will treat them as such, but dividing

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edge of the timbers, as shown in the lower left hand corner in Fig. 73c.

In this illustration we show both the regular and irregular miters for a square cornered frame, though it could be any polygonal corner. In this it will be seen that the regular miter is at 12 and 12 on the squares, and at 45 and 45 degrees from the edge of the timbers. In the irregular, the angle is at 58 and 32 degrees from the edge of the timbers, and on one of the squares it is at 12 and 19 5-24, and 12 and 7½ on the other, but either of the squares gives the same result as far as the miter is concerned.

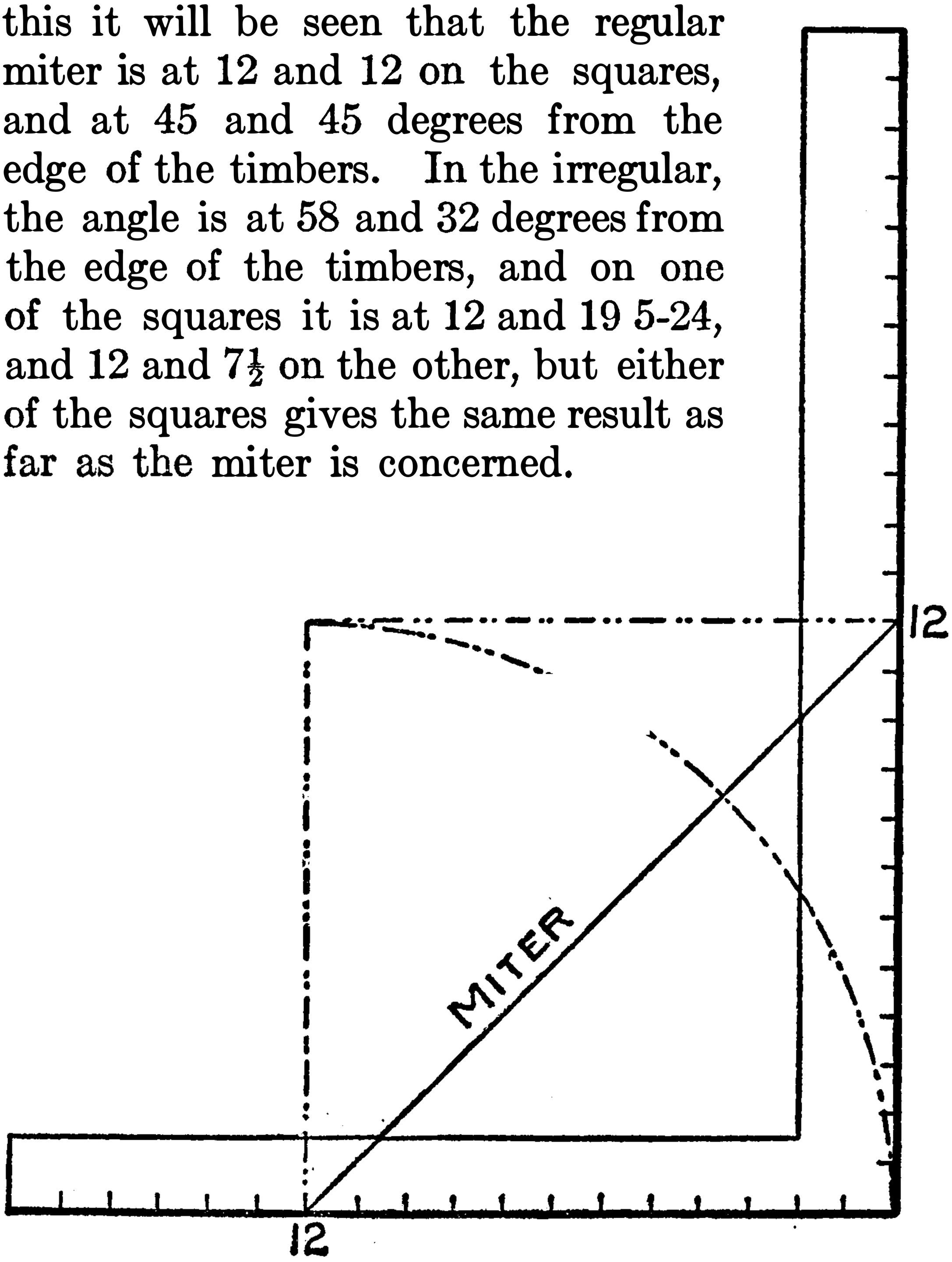

FIG. 74

The following is another article by Mr. Woods on bevels and hopper cuts generally, which owing to its excellency, we have thought worthy of

FIG. 75

a place in this work. The author starts out by saying: If there was no given pitch, then the sides would be vertical. Now with 12 on the

tongue as center, draw arc of same radius from the heel to a point directly above and square over the blade; 12 and 12 will give the miter, Fig. 74. Simple enough, but do you know that this simple rule applies when there is a pitch given? At the point where the arc intersects the pitch taken on the blade will give the miter, the blade giving the cut. See Fig. 75. For the side bevel across the board, transfer the length of the pitch to the blade, the tongue giving the cut. These figures also give the side cut of the jacks for a roof of same pitch. The blade in this case giving the cut.

Now we will give another method of finding the miter. In all roofs and hoppers there is an unseen pitch which we will call co-pitch. Assuming that the edges of our board are square the co-pitch would stand at an angle of 90 degrees with the given pitch. See Fig. 76.

The rule given in Fig. 75 for the side bevel will apply to the miter, but instead of using the length of the given pitch substitute that of the co-pitch, and by referring to Fig. 76 we find this to be $15\frac{3}{4}$ inches on the blade. Now for proof, see Fig. 77. Twelve and $9\frac{1}{8}$ first method, and 12 and $15\frac{3}{4}$ second method. The blade giving the cut in the former, and the tongue in the latter.

In Fig. 78 is shown all that is contained in the other figures, besides showing another pitch. It is an extension of the co-pitch to a point of the given pitch. This we will call complement

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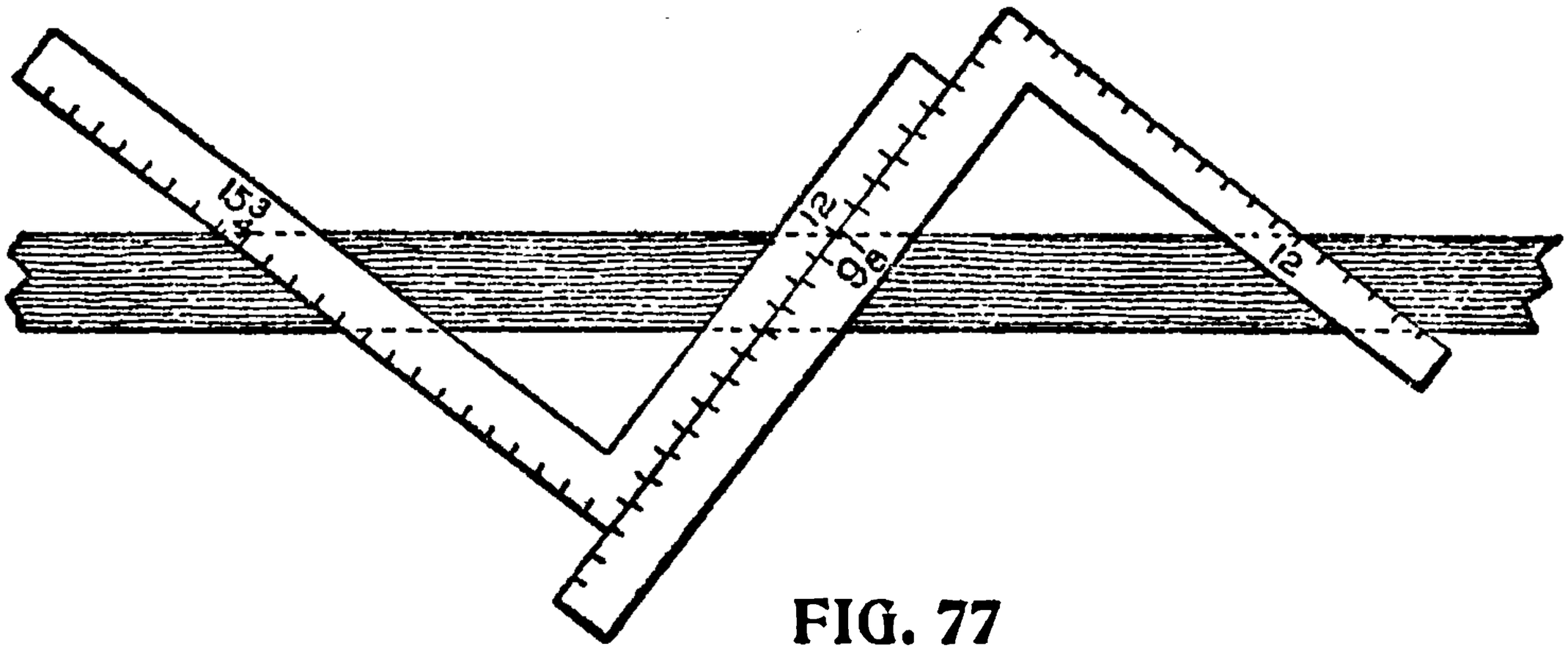

FIG. 77

pitch. The length of this pitch transferred to the blade will give the butt-joint or miter; the tongue giving the cut.

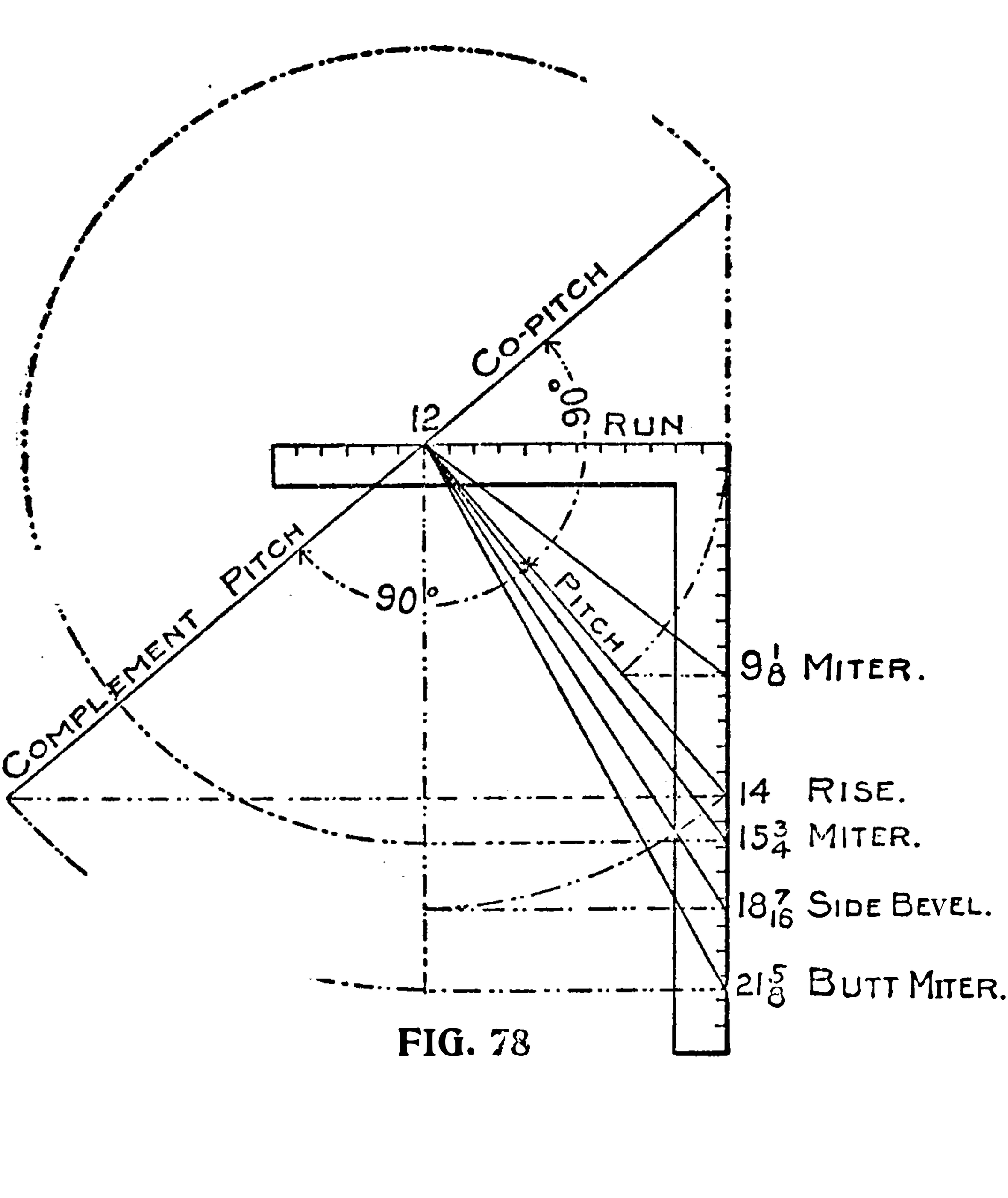

FIG. 78

In Fig. 79 is shown a diagram for a hopper of one-half pitch. In this all of the pitches are of equal length, therefore 12 and 16 and thirty-one-thirty-seconds will give all of the cuts; the

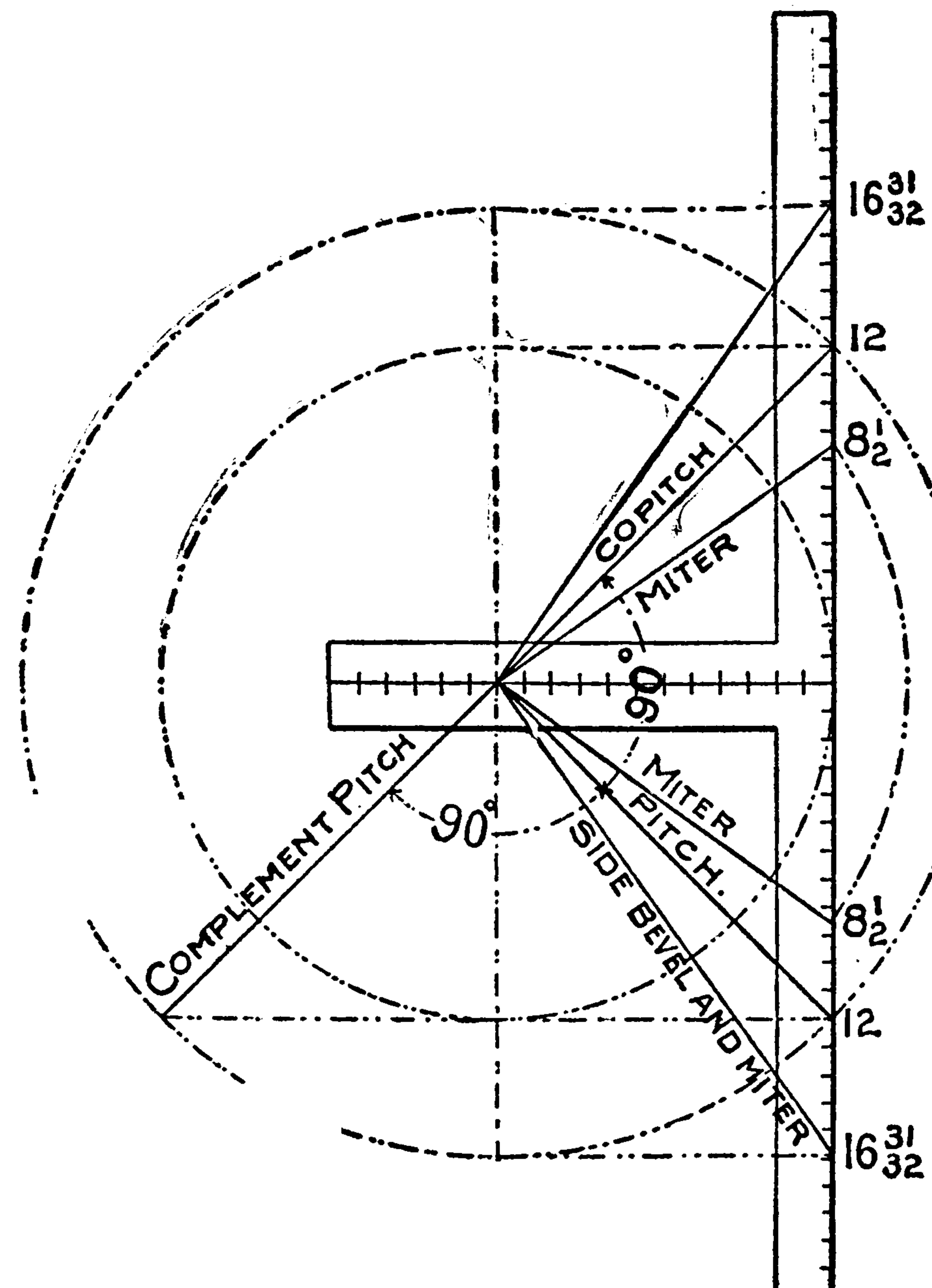

FIG. 79

tongue giving the cuts in each case. Fig. 80 and 81 are simply fillers and self-explanatory.

From the foregoing it will be seen that the standard of measurement is 12 on the tongue

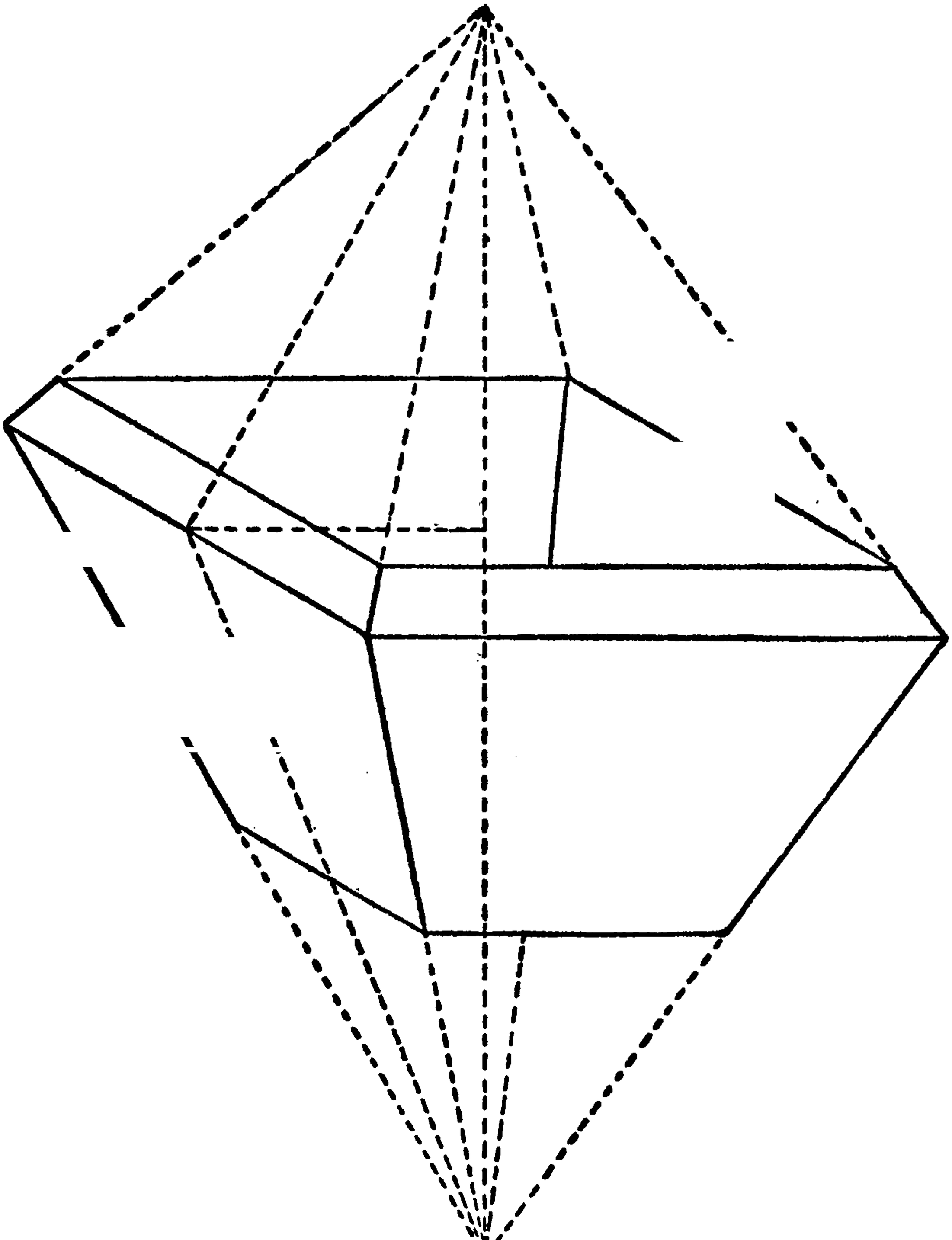

FIG. 80

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transferred from the blade to the tongue and 20 on the blade will give the cut across the face of the board.

In Fig. 83 is shown the second method: In this it will be seen that the same figures are used as in the first method for finding the miter cut.

FIG. 82

In this illustration we show two squares with their tongues together. The side cut is found the same as in the former figure, but in this another pitch is shown and which we will call the co-pitch. This pitch stands at 90 degrees from the given pitch of the hopper, provided the timber is square edged or at right angles with the side (though it may be at any angle). The rule is: Take the length of the co-pitch on the blade and 8 and 17-24 on the tongue and the latter will give the miter. This rule applies to any polygonal hopper. The figures to use on the tongue are always 12 and those that give the miter for a polygonal frame.

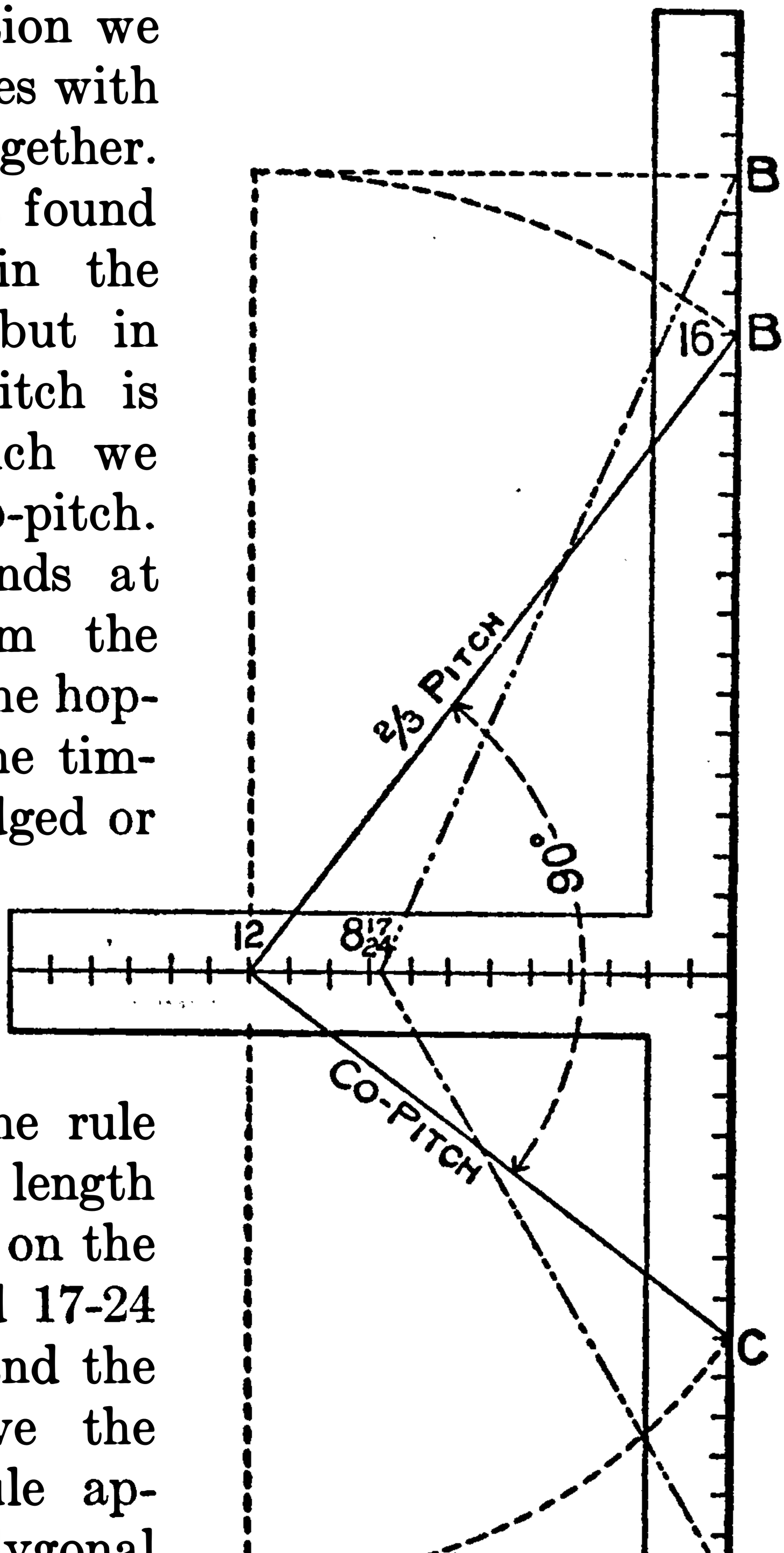

FIG. 83

In the case of a square hopper the tangent is equal the run (12) and for that reason only one set of figures on the tongue is used.

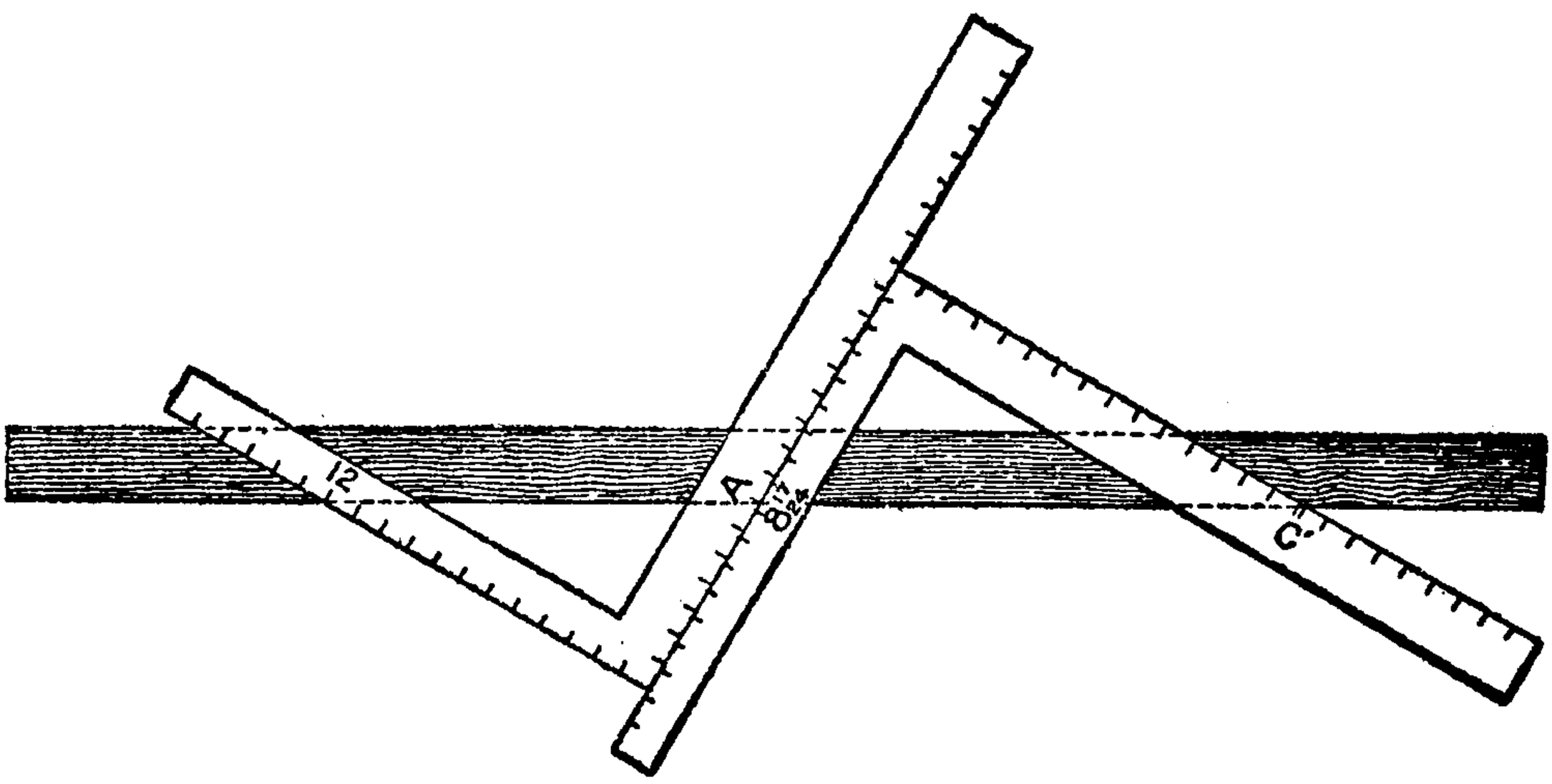

FIG. 84

In Fig. 84 is shown a proof of the two methods. The blade giving the cut in the former and the tongue in the latter.

Trusses.—In taking up the subject of trusses it is not our intention to enter into the subject further than the application of the Steel Square in obtaining the cuts and bevels. The rules for finding the cuts and bevels for common rafters and braces will apply to truss work in general.

In Fig. 85, A is the straining beam, B the brace, T the tie beam. Generally the brace has about one-third the length of tie beam for a run. From the rise and run find the length and lower end bevel of the brace. After marking the lower end bevel on the stick, add to it just what is cut out of the tie beam. The bevel of the upper end

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Fig. 86 represents the cross braces between the straining and tie beams. If the braces butt together as shown in the upper left hand corner of figure, the length and cuts are simply those for a common rafter having the same run and

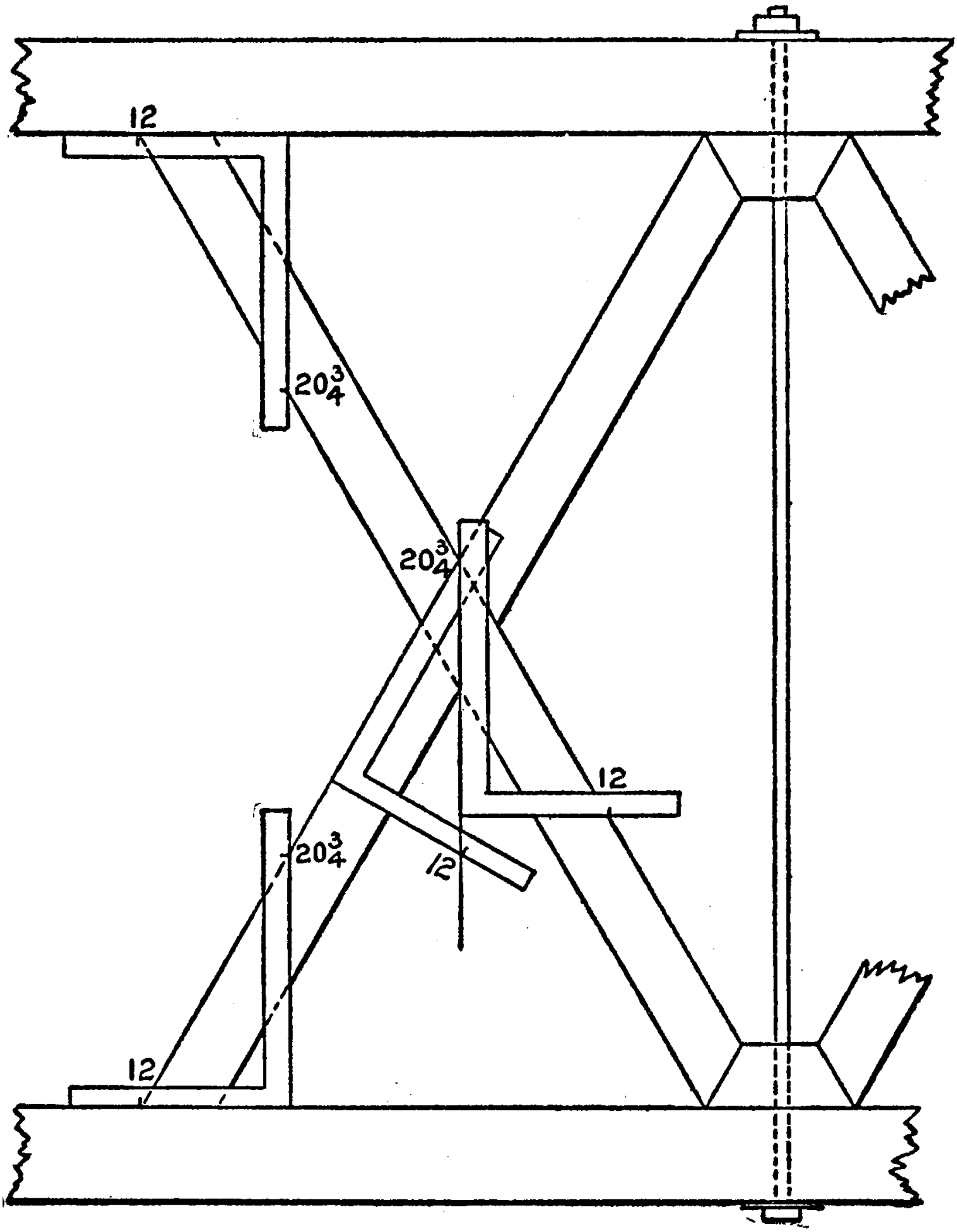

FIG. 86

rise. Usually a block of hard wood is used for the ends of the braces to rest against, as shown at the upper right hand corner, and in that case the angle may be found as for the brace against the beam.

These braces are sometimes halved at the center to allow the sides of the braces to be flush with each other. The angle of cut is found by applying the square with the figures that give the plumb cut of a rafter of same pitch; and to this without change of figures apply a second square as shown; this will give the proper angle across the brace from which to remove the wood.

Tower for Windmill, etc.—In connection with trusses we show in Fig. 87 a tower suitable for a windmill or for other similar purposes. The posts incline two inches to the foot—that is, two inches from the plumb line to every foot in the length of the post, and this incline is both ways. The length of post and bevels at the foot and top of posts may be found by applying the square as shown at R—that is, 24 inches on the blade and 4 inches on the tongue or 2 inches on the tongue and 12 inches on the blade, which is the same thing, so far as the bevels are concerned. These same figures also answer for the ends of the joists, S-S. We show in Fig. 88 the manner in which the bevels at the foot of the posts are marked. The dotted lines show the bevels on all sides, for, as the post leans two ways, the post must be beveled two ways. This, of course, will present itself to the workman as

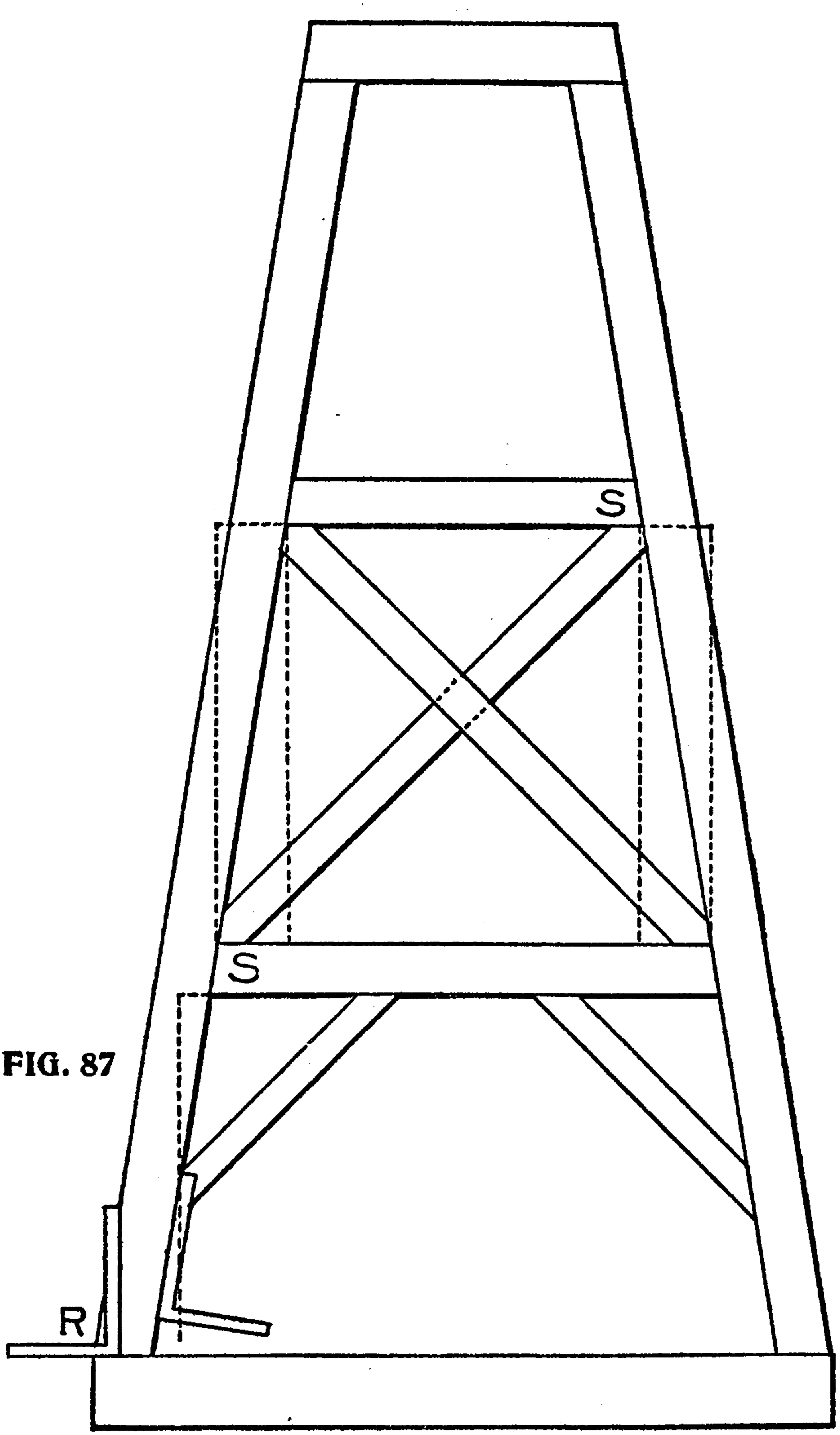

FIG. 87

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its heel at E. The distance from E to P is the same as from E to O. The overwood shown in this is somewhat exaggerated purposely, to give a clear idea of the requirements. The braces shown in this sketch will give the student an opportunity to figure. The lengths and bevels

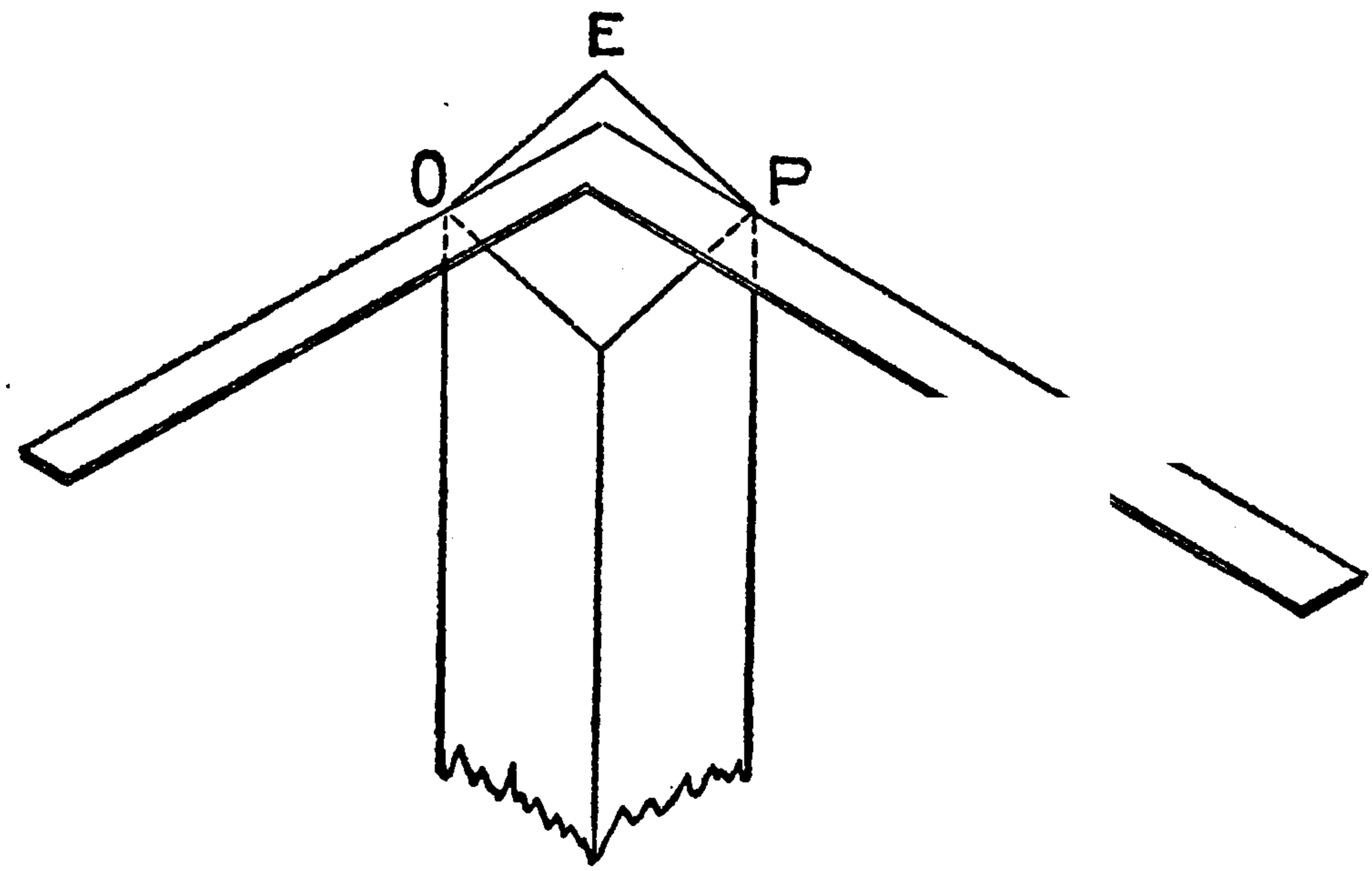

FIG. 89

may be obtained either by using the square or by taking them from a drawing, or by calculation.

We may observe at this point, that the posts in this structure are simply like the hips in a very steep roof or spire, and in a measure may be treated as such, but it will be seen that while the posts rest in the same position as the hip in the roof, its sides do not rest parallel with the plate as they do in the case of the tower.

Stair-Building

Although an entire volume can be devoted to the structure and kinds of stairs, we shall here dwell upon them only so far as the Steel Square is concerned in obtaining the run and rise.

To lay out a stairway properly and construct it, is an art in itself. The principles involved in the construction—even of ornamental types of stairs—are comparatively simple, but are in general only imperfectly understood, even by the workmen themselves who may be engaged in erecting them. It is exceedingly important for the carpenter to understand them.

How to Determine the Height and Run. —In laying out stairs with the square, it is necessary first to determine the height from the top of the floor from which the stairs start, to the floor on which they are to land; also the run or distance of their horizontal stretch. This is found by dividing the height into the number of rises desired in the stairway. This usually results in fractions of an inch to each rise, and somewhat complicates the work. However, the fractions may be avoided by the use of the story pole by spacing it off with a pair of compasses into the number of risers desired in the stairs. This being done, the rest is comparatively easy, because the run or horizontal stretch is not usually limited as to exact space as in the case of the rise of the

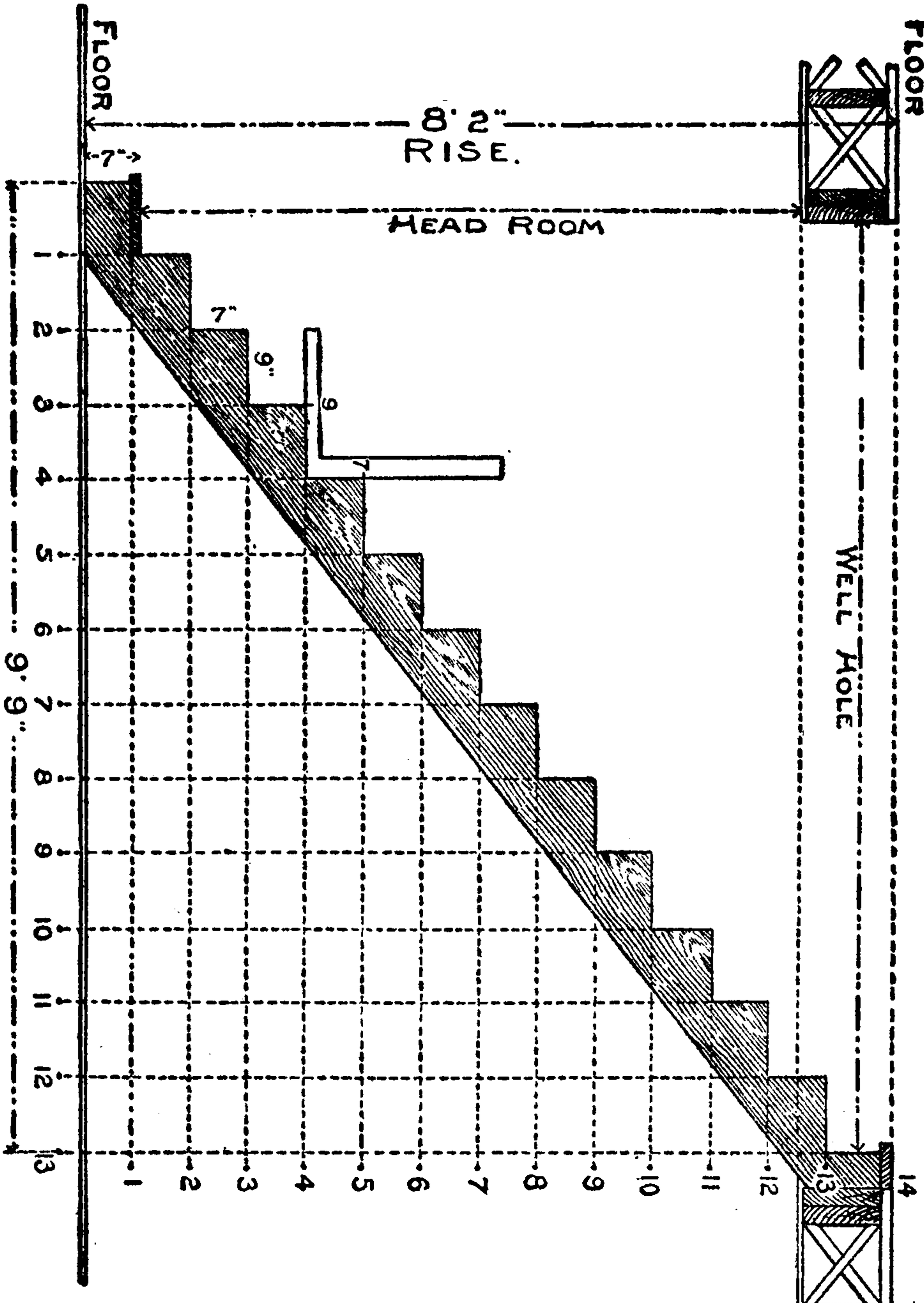
FLOOR
8' 2"
RISE.
7"
HEAD ROOM
7"
9"
9
WELL HOLE
FLOOR
RUN.
9' 9"
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIG. 90

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a piece of thin, clear stuff, and lay the square on the face edge, as shown in the figure, and mark out the pitch-board with a sharp knife; then cut out with a fine saw and dress to knife marks, nail a piece on the largest edge of the pitch-board for a fence, and it is ready for use.

Illustrations of the Pitch-board.—The next thing to be considered is what is the manner of

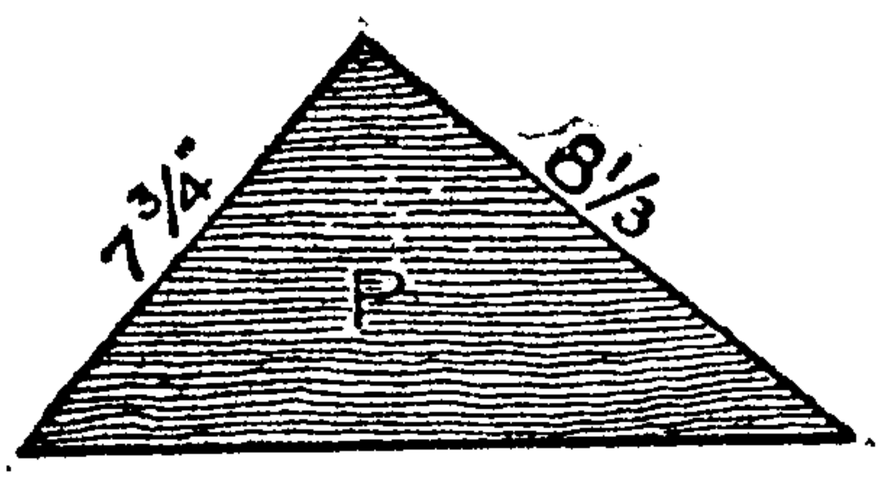

FIG. 92

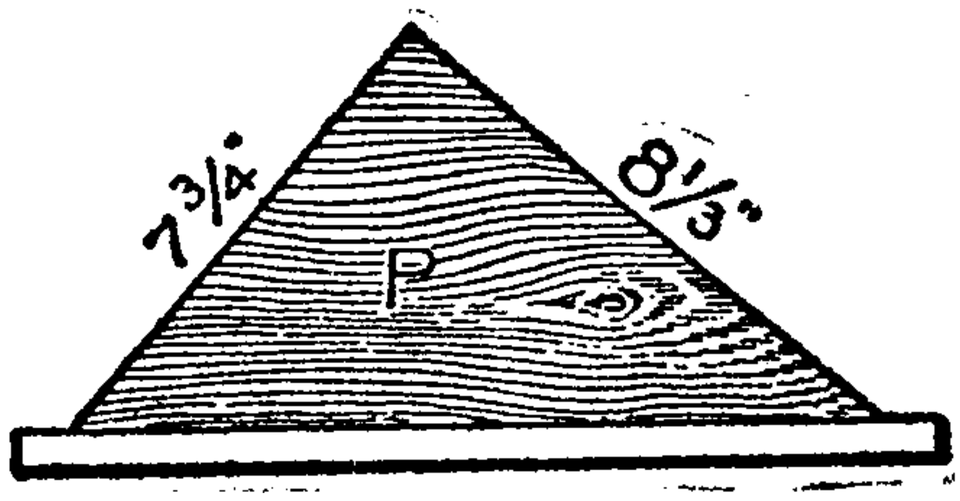

FIG. 93

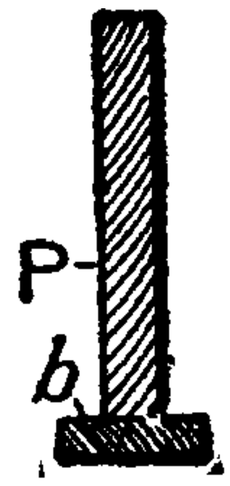

FIG. 94

using the pitch-board? Before showing its use, however, we wish the learner to have a thorough conception of what the pitch-board is, and with that object we show and explain the following illustrations. Fig. 92 shows the pitch-board pure and simple; it may be an inch thick, or if of hard wood, may be from a quarter to a half an inch thick.

Fig. 93 shows the pitch-board after the gauge or fence is nailed on. This fence or gauge may be about one and one-half inches wide, and from $\frac{3}{8}$ to $\frac{3}{4}$ of an inch thick. Fig. 94 shows a sectional view of the pitch-board with the fence nailed on as at bp, which shows the edge of the board.

Manner of Using the Board.—Fig. 95 shows the manner of applying the board. R,R,R,R, is

the string, and the line A shows the jointed or straight edge of the string. The pitch-board, p, is shown in position, the line $8\frac{1}{3}$ represents the step or tread, and the line $7\frac{3}{4}$ shows the line of the riser. These two lines are of course at right angles, or as the carpenter would say, "they are square." This string shows five complete cuts for treads, and six complete cuts for risers. The bottom of the string at W is cut off at the line of the floor on which it is supposed to

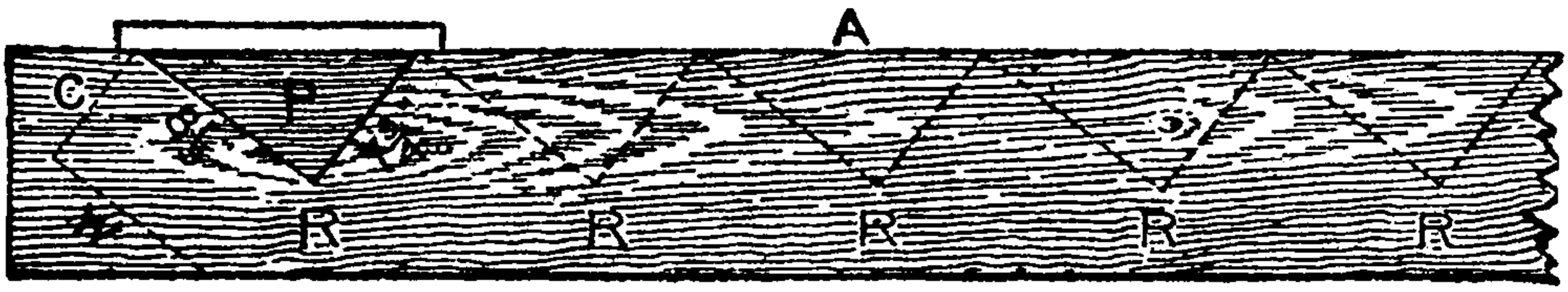

FIG. 95

rest. The line C is the line of the first riser. This riser is narrower than any of the other risers, because the thickness of the first tread is always taken off it; thus, if the tread is $1\frac{1}{2}$ inches thick, the riser in this case would only require to be $6\frac{1}{4}$ inches wide, as $6\frac{1}{4}$ and $1\frac{1}{2}$ inches together make $7\frac{3}{4}$ inches. Another thing to be considered is the string, which must be cut so that the line at W will be only $6\frac{1}{4}$ inches from the line at $8\frac{1}{3}$, and it must be parallel with it. The first riser and tread having been satisfactorily dealt with, the rest may be easily marked off by simply sliding the pitch-board along the line A until the line $8\frac{1}{3}$ on the pitch-board strikes the line $7\frac{3}{4}$ on the

string, when another tread and another riser are marked off in the same manner.

Open Strings.—Fig. 96 shows a portion of the stairs in position. S, S, shows the strings, which in this case are cut square; that is, the part of the string to which the riser is joined is cut square across, and the "butt" or end wood of the riser is seen. In this case, also, the end of the tread is cut square off and flush with the string and riser. Both strings in this instance are open strings.

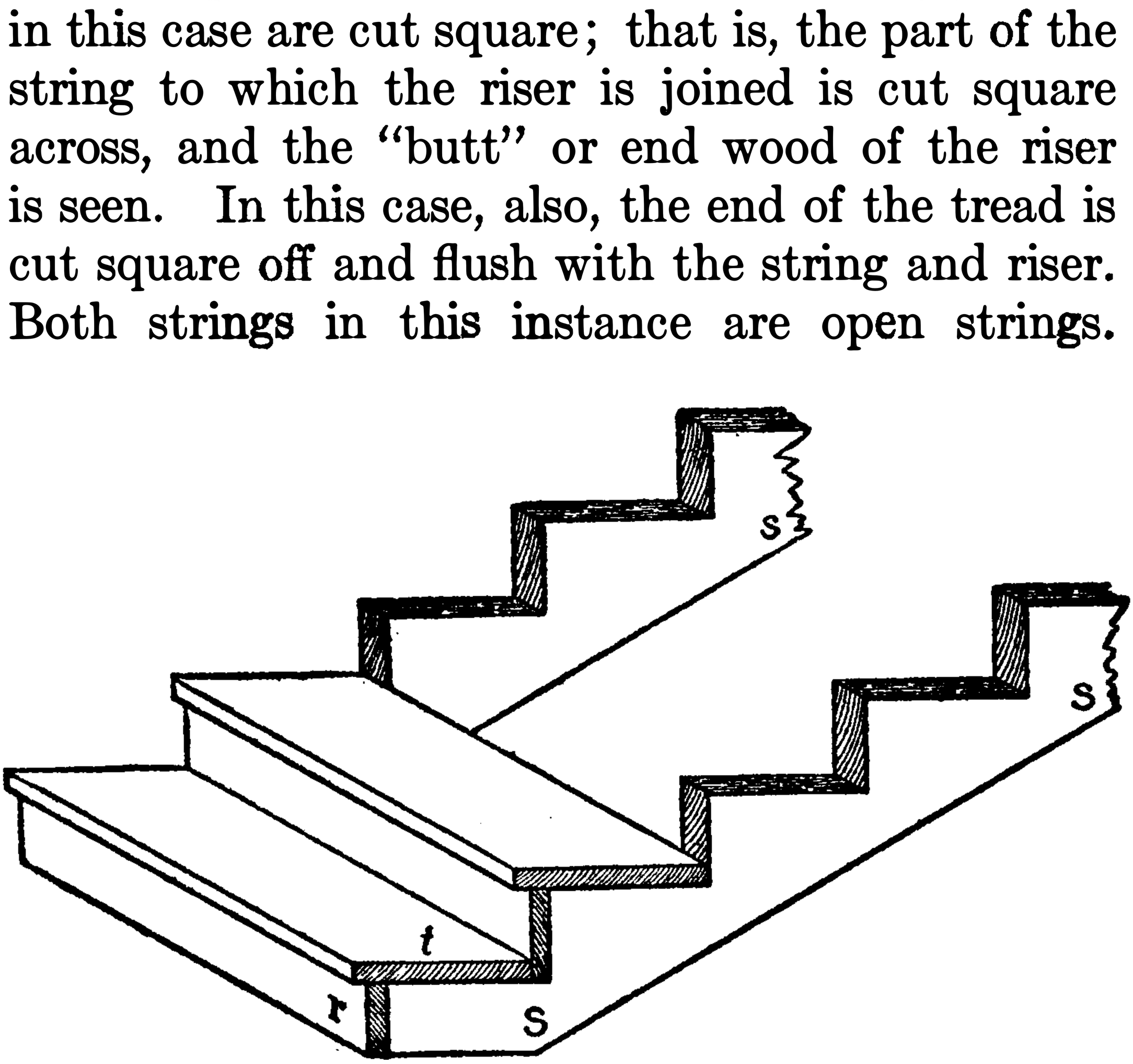

FIG. 96

Usually in stairs of this kind, the ends of the treads are rounded off similar to the front of the tread, and the ends project over the strings the same distance that the front edge projects over the riser. If a moulding or "cove" is used under the nosing in front, it should be carried round on the string to the back edge of the tread, and cut off square, for in this case the back edge of the

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three of these blocks should be used at about equal distances apart, putting the two outside ones about six inches from the strings. They are glued in the angle.

It will be noticed that the riser has a lip on the upper edge, which enters into a groove in the tread. This lip is generally about $\frac{3}{8}$ inches

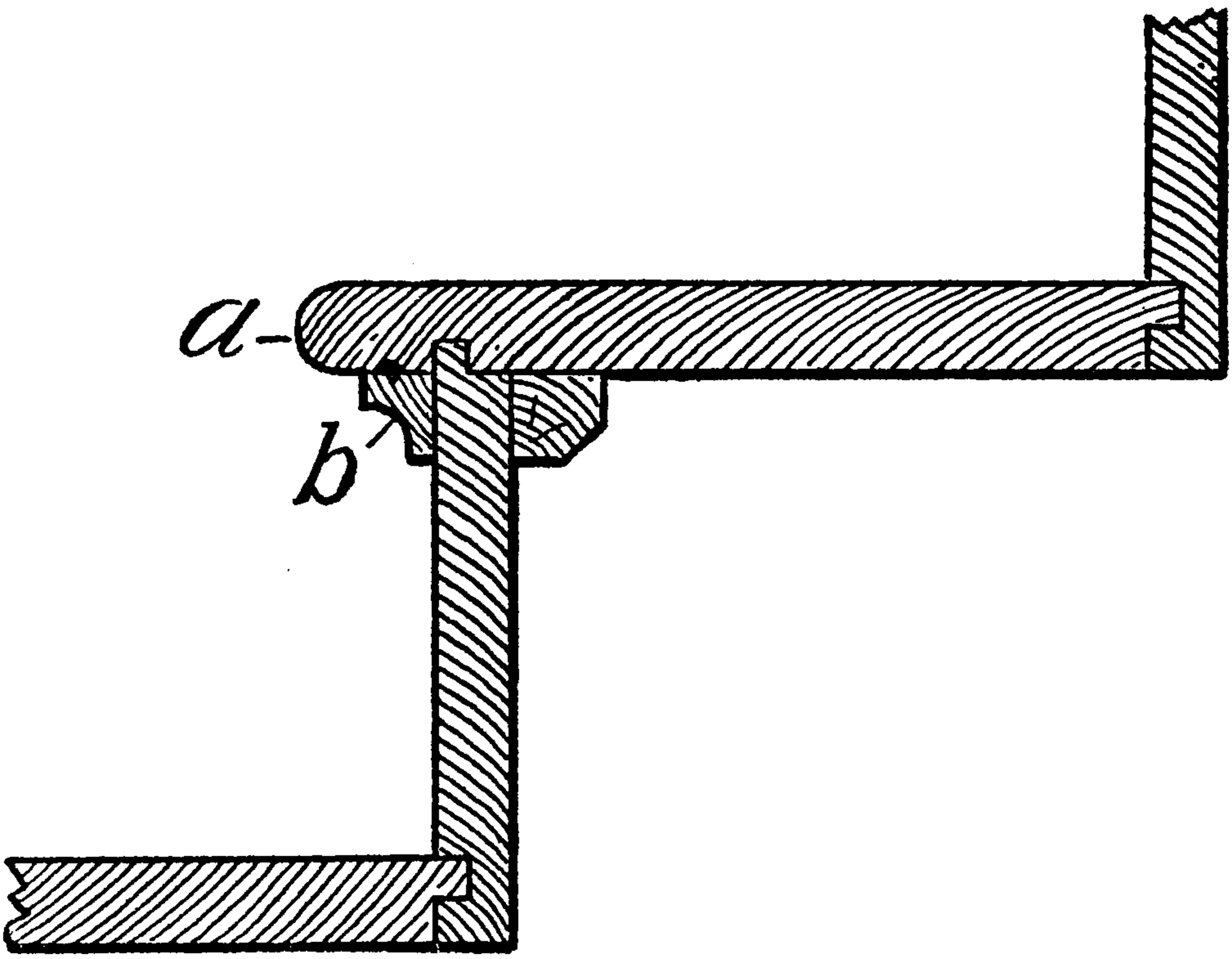

FIG. 98

long, and may be $\frac{3}{8}$ or $\frac{1}{2}$ of an inch in thickness. Care must be taken in getting out the risers, that they are not made too narrow, as allowance must be made for the lip. If the riser is a little too wide it will do no harm, as the overwidth may hang down below the tread; but it must be made the exact width where it rests on the string.

The treads must be made the exact width required before they are grooved or the nosing worked on the outer edge. The lip or tongue on the riser should fit snug in the groove and bottom. By following these last instructions, and seeing that the blocks are well glued in, a good solid job will be the result.

In Fig. 98 a scheme for the construction of the tread and riser is shown. The tread has a lip worked on it at the back edge, which enters a groove ploughed in the riser. The riser also has a lip left on the upper edge, which goes into a groove made in the tread similar to the method shown in Fig. 97.

The cove is shown at b, and the angle block is also represented. This makes a very solid step when well put together, and, where the steps are to be of the better kind, this method of constructing the step may be adopted with advantage. This method is a favorite one with stair builders, and has proved to be a substantial one, though it costs a little more than the ordinary method.

Housed or Closed Strings.—Fig. 99 represents a housed or closed string. In this the risers and treads are let into the strings from the back side.

Gauge lightly a line from the upper edge of the string, the distance intended to stand above the treads as shown in the dotted line. On this line apply the pitch-board, as explained on previons pages. In laying out housed strings, it is as well to take the fence off the pitch-board, as it can be handled better without it, as the long

side will have to be kept close to the gauge line, to insure good work. The top lines for treads and the face lines for risers, are the lines that define the step, and cannot be changed; but the back line of the riser and the lower line of the tread should be made to run so that the housing or

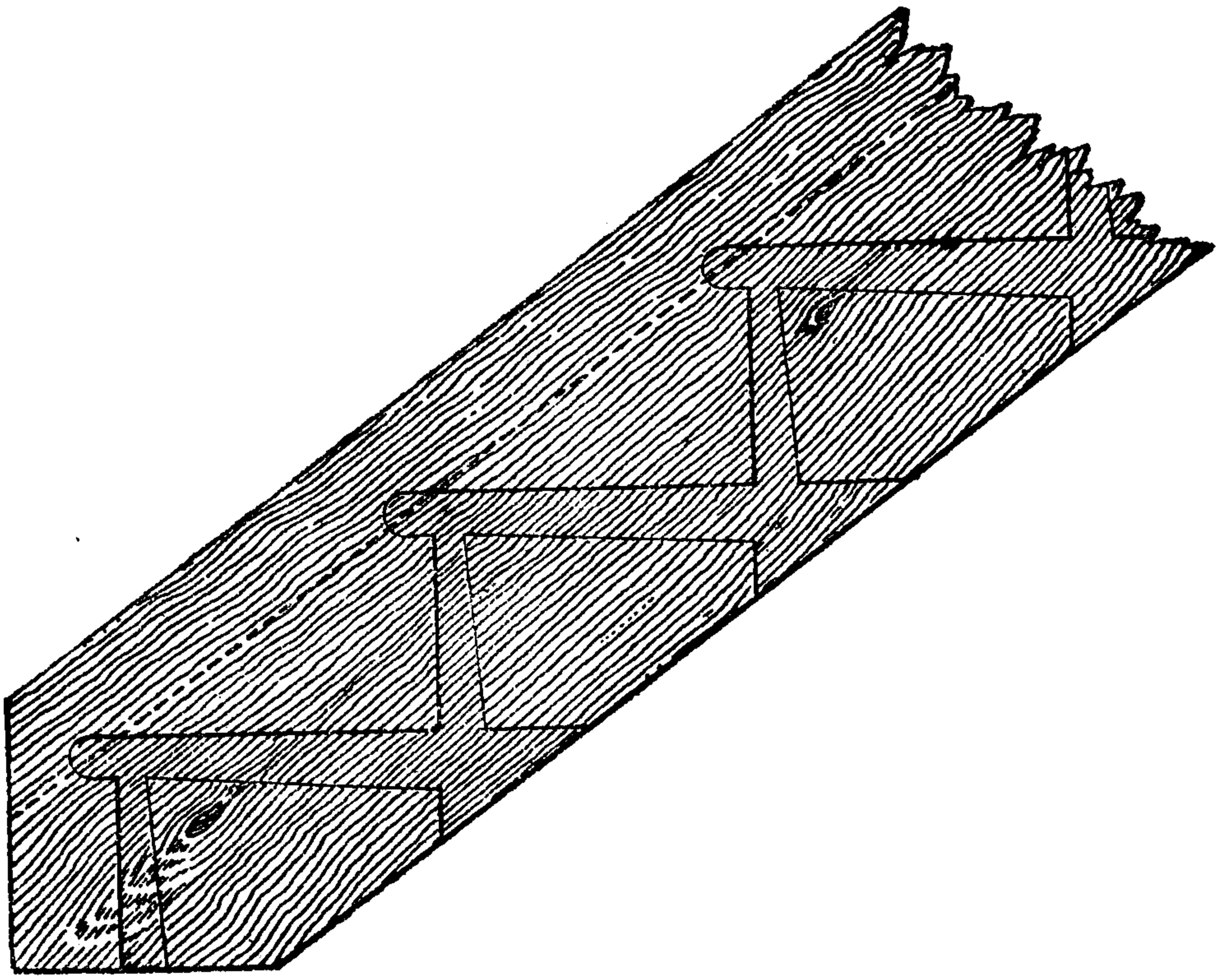

FIG. 99

groove will be wider at the under side of the string than at the junction of the riser and tread at the nosing, where the grooves will be the same width as the riser and tread are in thickness separately. The nosing projects over the riser, as will be seen, and to mark this portion out, it is usual to make

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face of the riser and top of the tread, then a fine tenon saw should be used to saw down to the exact depth. This will not be difficult to perform when the hole forming the nosing recess has been bored to the proper depth. A gauge line should be made on the back edge of the string to indicate the depth of the housing. Care should be taken in removing the wood from the grooves, that too much is not taken or the grooves made too deep. A gauge for trying the depth may be made out of a piece of hard wood, say about four inches long and three inches wide, by about one-half inch in thickness. Make a tenon on the center of one end, about three-quarters of an inch in width, and cut the shoulders back sufficiently to admit the tenon being long enough to touch the bottom of the groove or housing, when the shoulders rest on the face of the string.

In Fig. 100 we show a sectional elevation through the steps. The treads, t, t, and the risers, r, r, are shown in position. These are secured, as will be seen, by means of the wedges, x, x, and y, y, which are well covered with glue before they are inserted and driven home. Stairs made after this manner are strong and perfectly solid under foot.

Other Methods of Making a Stair String.—We have now shown you the way to make an open string and how to make a housed string. There are several other methods of making a stair string than those shown already; one way is to form two tenons on the end of the tread, which fit

into mortises cut through the string. This method makes a very strong stair if the string is wide enough to allow for the loss of strength caused by making the mortises.

In Fig. 101 several ways of forming an open string are shown. Different methods of uniting the risers and treads are shown. They may be

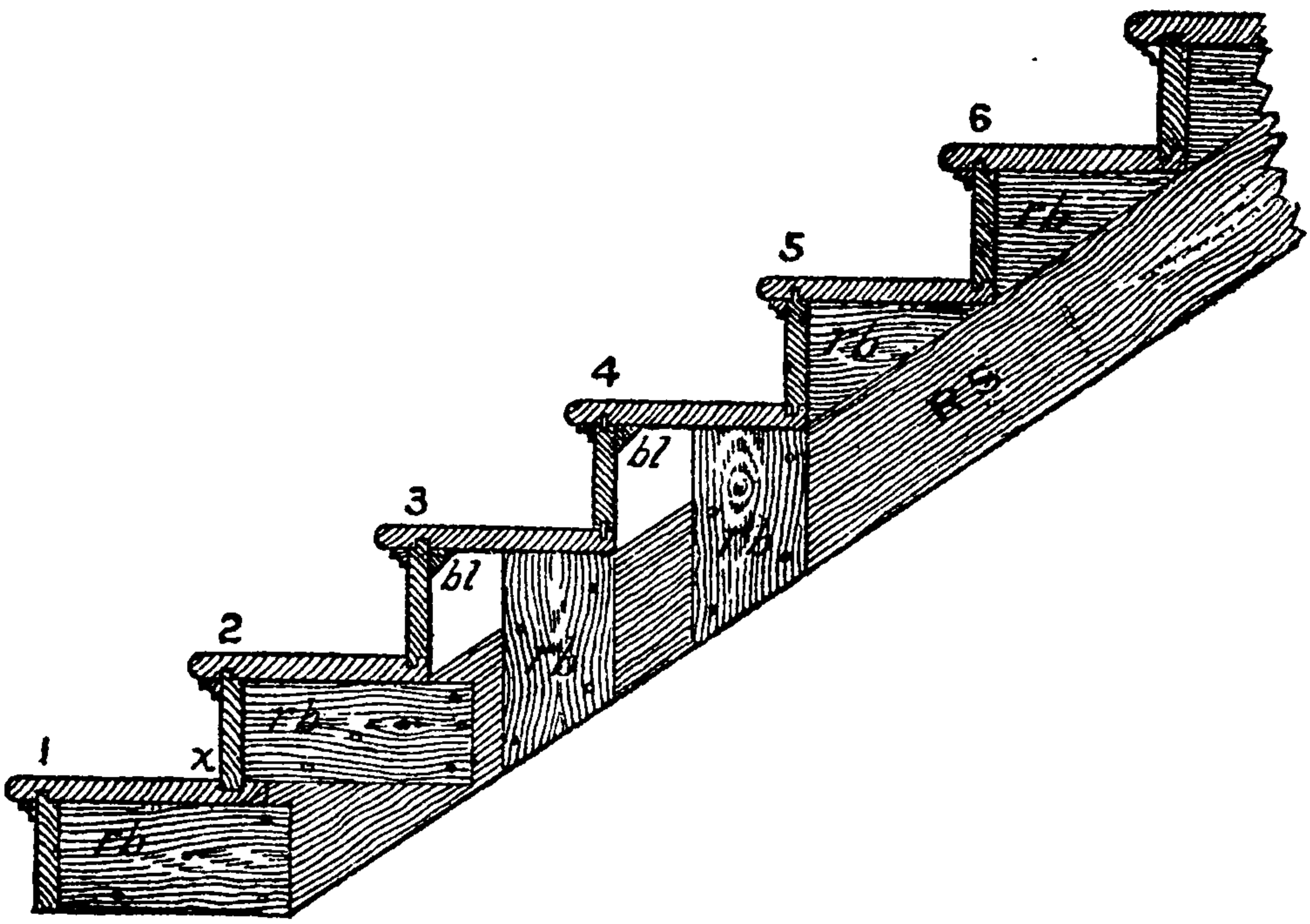

FIG. 101

grooved and tongued, as in steps 5 and 6, or feathered as in step 4, or rabbeted as as step 3; in every case the joint should be glued and blocked. Sometimes the riser is housed into the tread as at X. The tread is also sometimes tongued into the riser, but this is not good construction, and should be avoided. R, S, show a rough string or scantling, having pieces, r, b, steps 2, 3 and 4, nailed or screwed onto it to support the treads.

Triangular pieces may be nailed on the top edge of the scantling to support the treads, as shown at steps 5 and 6. A rough string, corresponding to the open string, may be used in place of any of the foregoing methods. The under edge of all rough strings should be made to coincide with the lower edge of the furring or cleat, nailed on the inside lower edge of the outside cut string, and so arranged that the lathing will nail on the furring, the rough strings, and the lower edge of the wall string.

Connecting and Affixing Strings.—We have now described several methods of dealing with strings, but there still are several other things connected with strings, both housed and open, that will be necessary to explain before one can proceed to put up a fair flight of stairs. The connection of the wall string to the base of the lower and upper floors, and the manner of affixing the outer or cut string to the upper joist and to the newel are matters that must not be overlooked, and we intend to show how these things are accomplished. We will proceed now to describe the method of finishing the tread and riser at the end of the step that rests on the outer string.

Fig. 102 gives two views of a portion of a better-class stair, a stair with cut and mitered string, or open string stair. In referring to the plan W S, shows the wall string; RS the rough string placed there to give the structure strength; and OS the outer or cut string. At a, a the ends of the risers are shown, and it will be noticed that

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outer end of the tread is also mitered at the nosing, and a piece of stuff made or worked like the nosing is mitered against, or returned at the end of the tread. The end of this returned piece is again returned on itself back to the string, as shown in the upper portion of the cut at n. The moulding, which is a five-eights cove in this case, is also returned round the string and into itself.

Balusters.—The mortises shown at the black points, B, B, B, etc., are for the balusters. It is always the proper thing to saw the ends of the tread ready for the balusters before they are attached to the string, then when the time arrives to put up the rail, the back end of the mortise may be cut out, when the tread will be ready to receive the baluster. The mortise is dovetailed, and, of course, the tenon in the baluster must be made to suit. The tread is finished on the bench, and the return nosing is fitted to it and tacked on, so that it may be taken off to insert the balusters, when the rail is being put into position.

Brackets.—In Fig. 103 we show the end of a step on a cut and mitered string, which is bracketed. B shows the bracket and the manner in which the end is finished. Brackets on stairs are generally about $\frac{3}{8}$ of an inch thick, and may be of almost any design that is in keeping with the surroundings. When a stair is bracketed, the point of the riser on its string end should be left standing past the string, the thickness of the bracket, and the end of the bracket miters against it, thus avoiding the necessity of showing end wood or

joint. The cove should finish inside the length of the bracket, and the nosing should finish outside the length of the bracket. When brackets are employed, they should continue along the cylin-

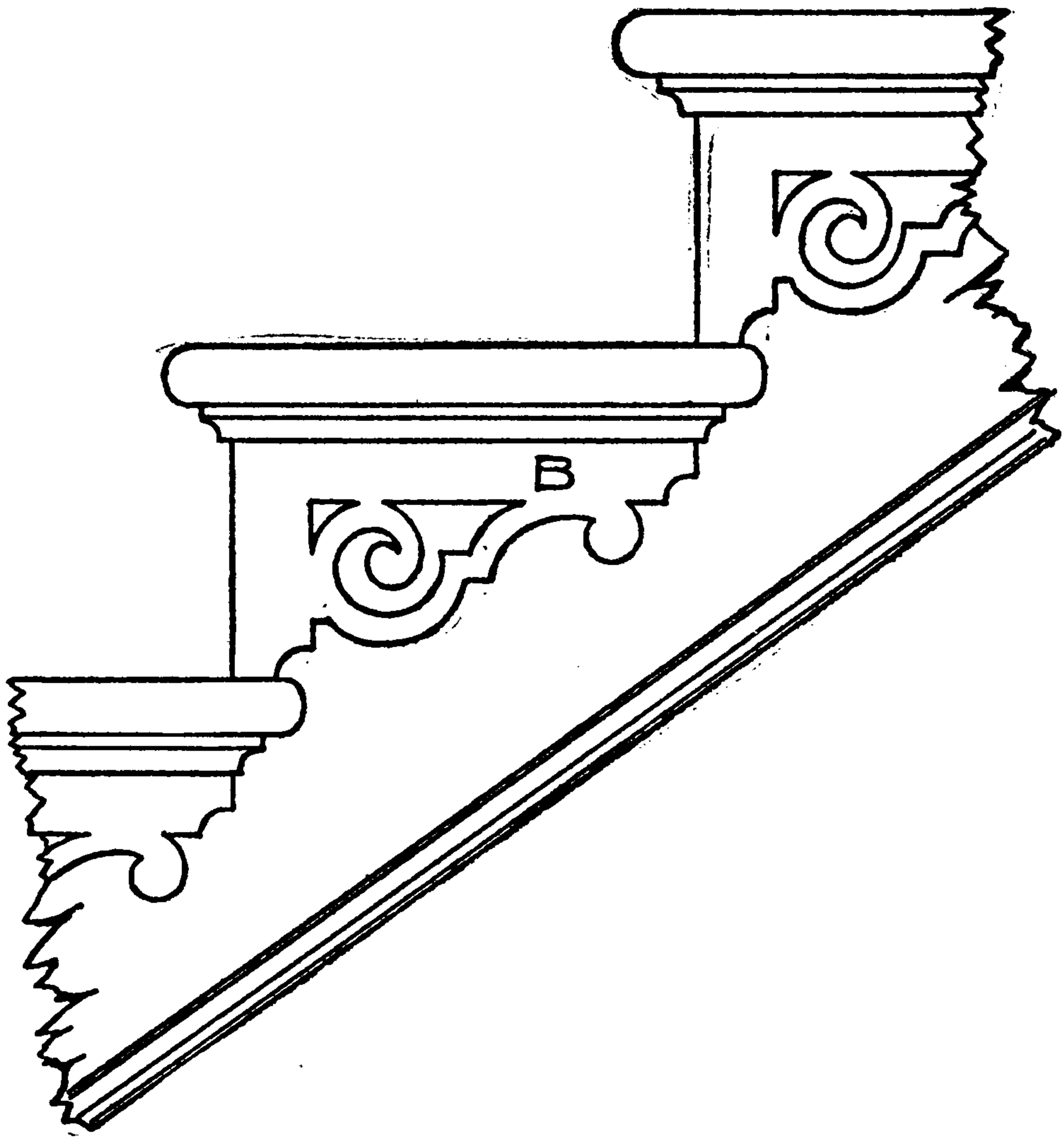

FIG. 103

der, and all around the well hole and trimmers, though they may be varied to suit conditions when continuously running on a straight horizontal facia.

Finish of Wall String at Foot of Stairs.—Fig. 104 shows the manner in which a wall string is finished at the foot of the stairs. S shows the string, with a moulding wrought on the upper edge. This moulding may be a simple ogee, or may consist of a number of members, or may be only a bead, or the edge of the string may be left quite plain; this will be regulated in a great meas-

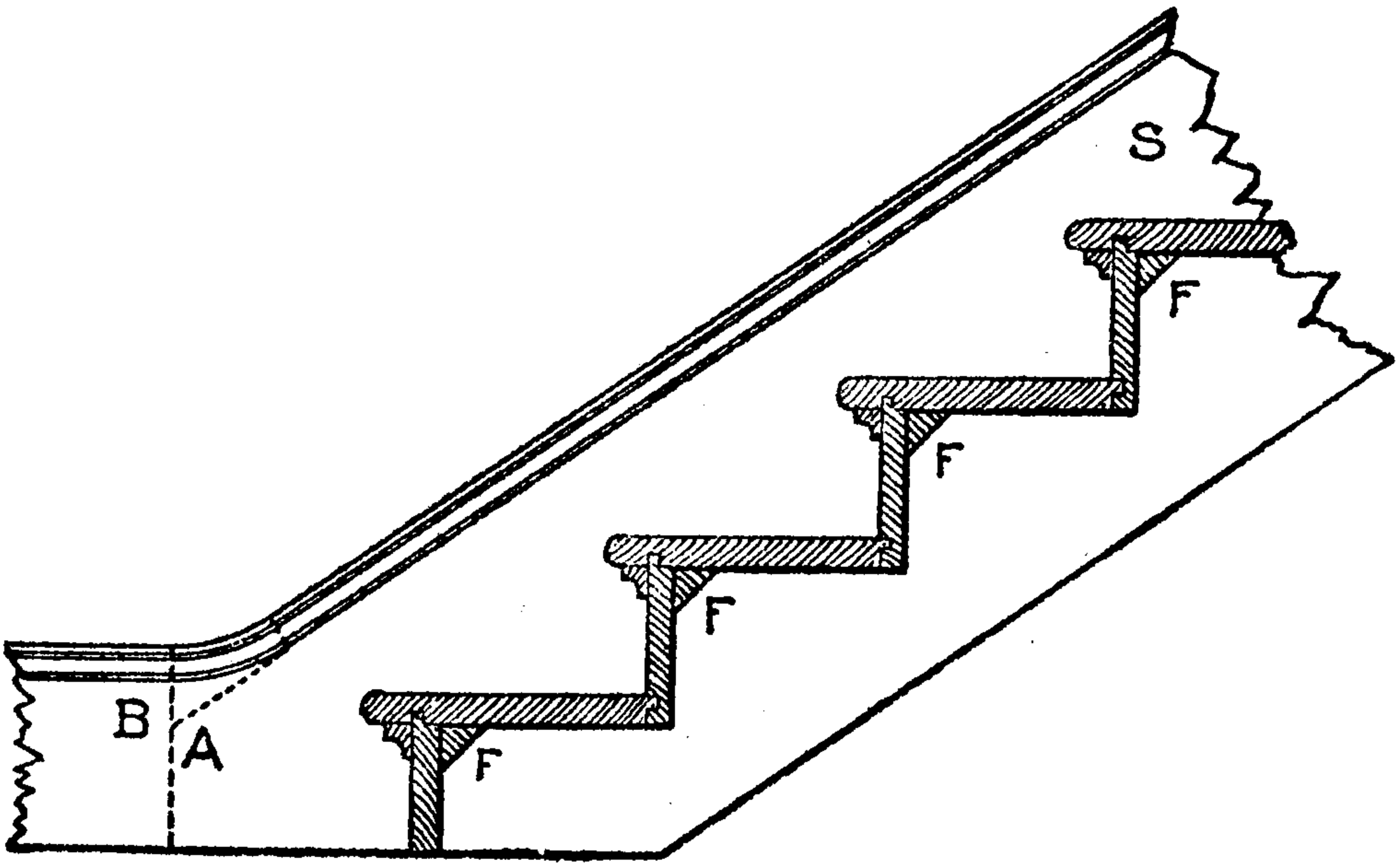

FIG. 104

ure by the style of finish in the hall, or wherever the stairs are placed. B shows a portion of the baseboard, the top edge of which has the same finish as the top edge of the string. B and A together show the junction of the string and base. The dotted line shows when a piece of stuff has been glued onto the string to make it wide enough at the junction to get the ease-off or curve. F,

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the manner of dealing with it at its juncture with the newel post K. The point of the string should be mortised into the newel two, three or four inches, as shown by the dotted lines, and the mortise made in the newel should be made near the center, so that the center of the baluster will be directly opposite the central line of the newel post. The proper way to manage this is to meas-

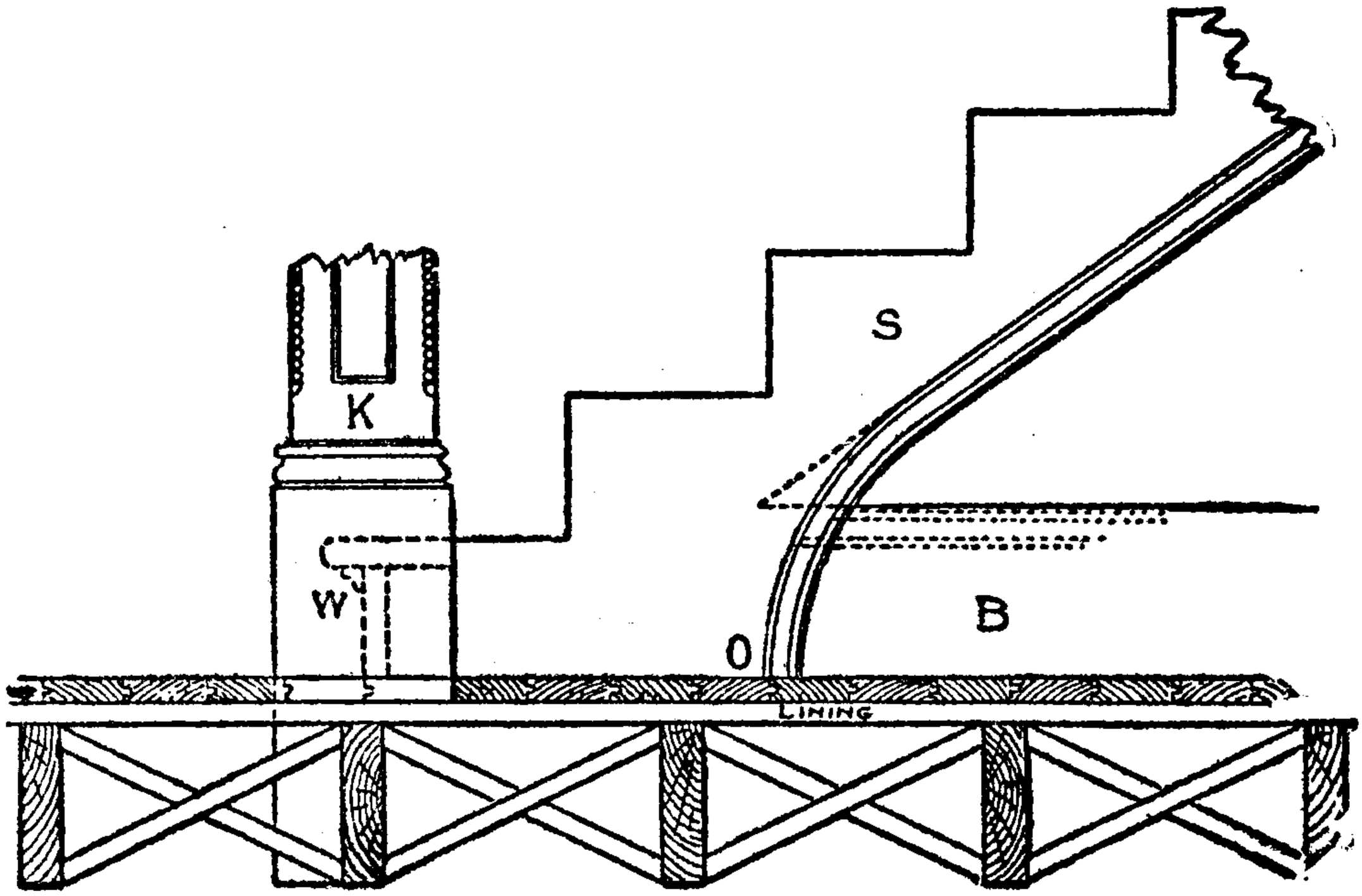

FIG. 106

ure the central line of the baluster on the tread, and then make this line correspond with the central line of the newel post. By a careful attendance to this matter, much trouble will be avoided where a turned cap is used to receive the lower part of the rail. The lower riser, in a stair of this kind, will be something shorter than the ones that follow it, as it must be cut between the

newel and the wall string. A portion of the tread, as well as the riser, will also butt against the newel, as shown at W. If there is no spandril or wall under the open string, it may run down to the floor, as shown at O. The piece O is glued onto the string, and the moulding is worked on the curve.

If there is a wall under the string S, then the base B, shown by the dotted lines, will finish against the strings, and it should have a moulding stuck on its upper edge the same as the one on the lower edge of the string, if any, and this moulding should miter into the one on the string. When there is a base, the piece O is dispensed with.

The square of the newel should run down by the side of a joist, as shown, and be firmly secured to it by iron knees or other suitable devices. If the joist runs the other way, try and get the newel post against it, if possible, either by furring out the joist or cutting a portion off the thickness of the newel. The solidity of a stair, and the firmness of the rail, depend very much on the rigidity of the newel post.

Fig. 107 shows how the cut string is finished at the top of the stairs. This illustration requires no explanation after the foregoing has been examined.

So far we have dealt with those stairs having a bevel at the bottom only; however, there are many modifications of straight and return stairs, that have either two, four or six newels. When

any of those conditions arise, the treatment of strings at their finishing points will necessarily be somewhat different than that described, but the general principles, as shown and explained,

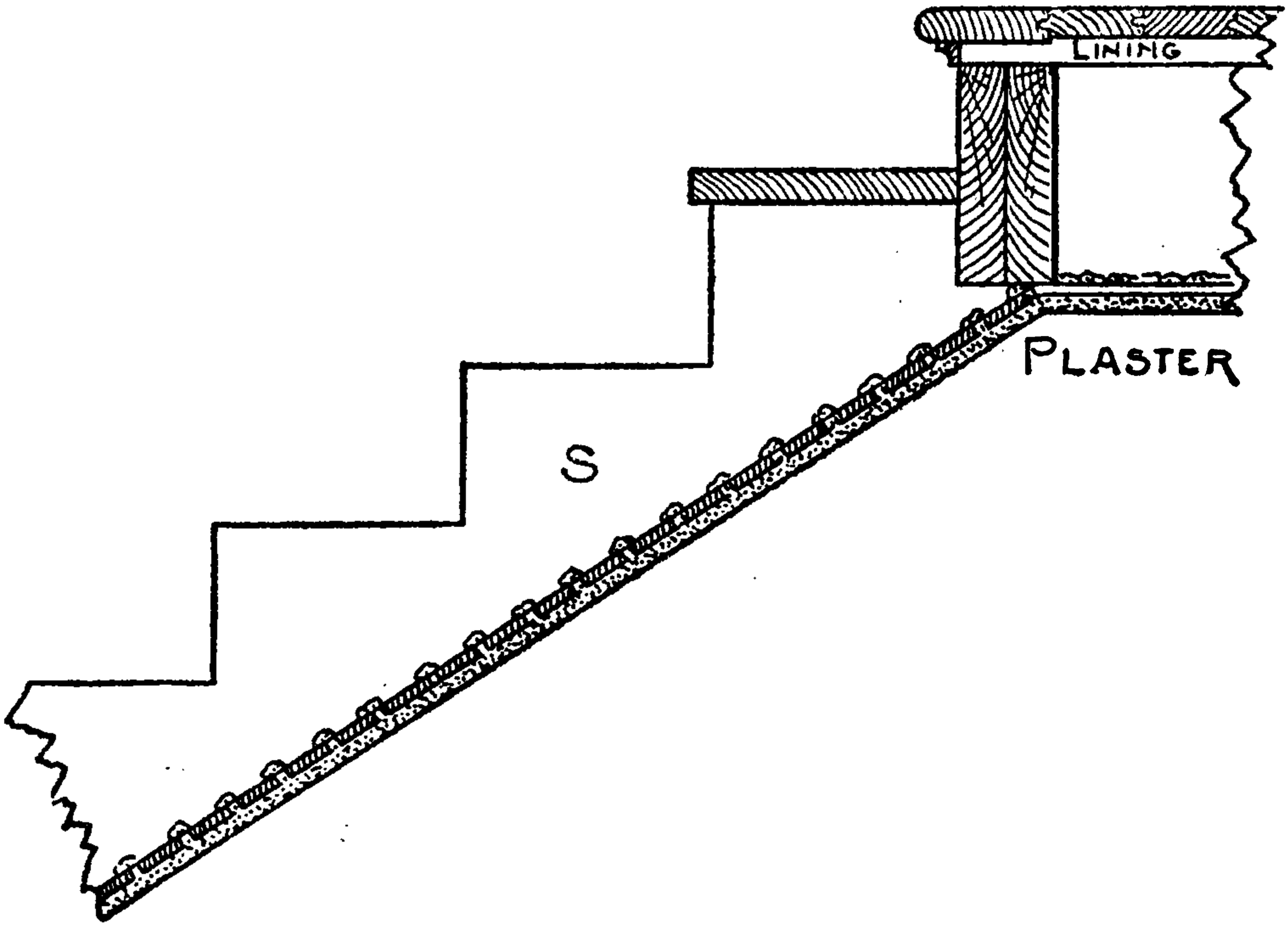

FIG. 107

will hold good. As this work is only intended to cover the simpler class of stair building, we will not enter into the more complicated phase of the work.

Miter Boxes.—One of the most troublesome things the carpenter meets with is the cutting of a spring moulding when the horizontal portion has to miter with a gable or raking moulding. Undoubtedly the best way to make good work of these mouldings is to use a miter-box. To do this make the down cuts B, B (Fig. 108) the

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right angle, measure respectively 12 and 13½ inches as shown in Fig. 110.

The lines A and B show the top of the miter box with the lines marked on. The side

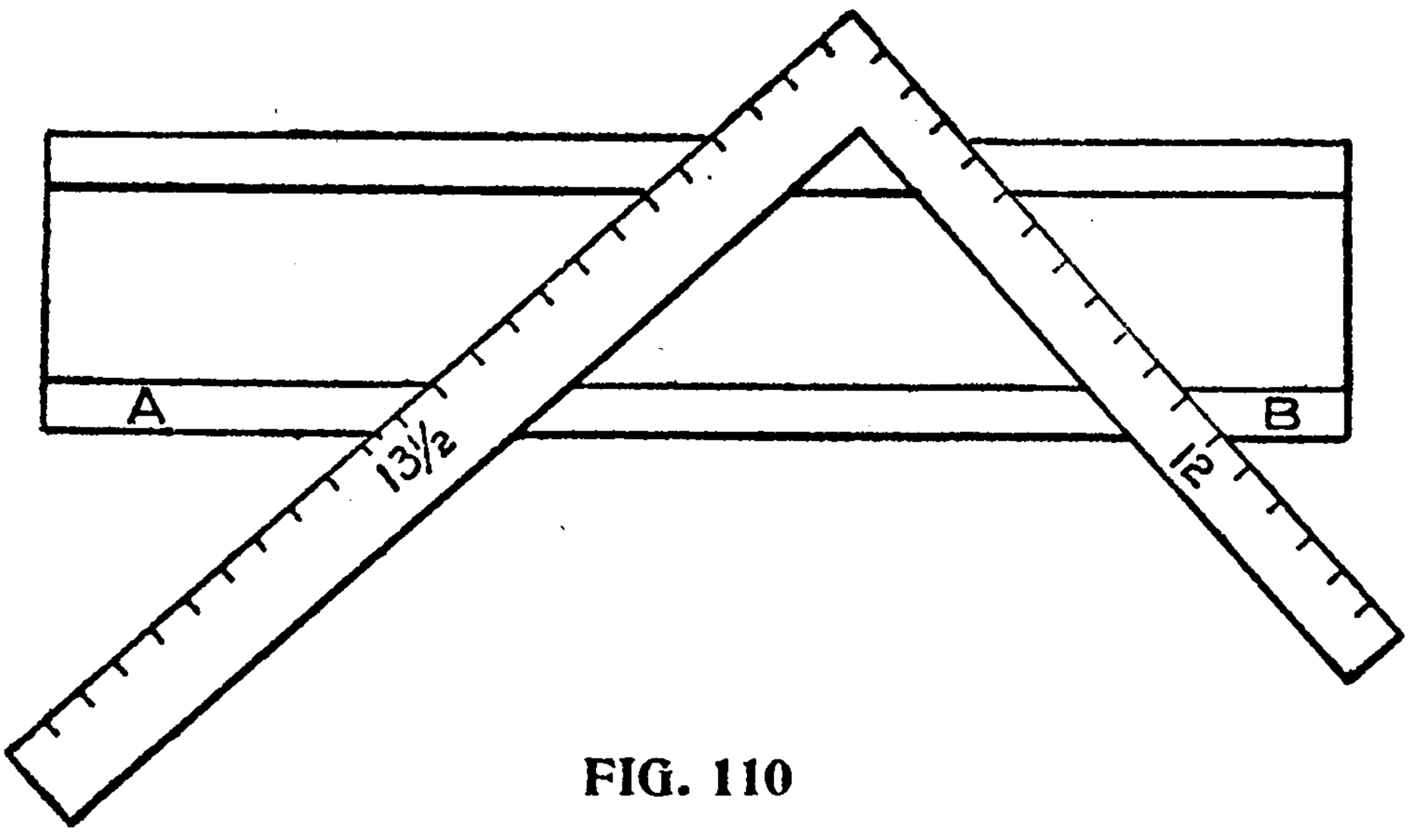

FIG. 110

marked 13½ inches is the side to mark from; this must be borne in mind, and it must be remembered that this bevel must be used for both cuts, the 12-inch side not being used at all.

Another excellent method for obtaining the section of a raking mould that will intersect a given horizontal moulding, is given below, also the manner of finding the cuts for a miter box for same. The principles on which the method is based being, first, that similar points on the rake and horizontal parts of a cornice are equally distant from vertical planes represented by the walls of a building; and, second, that such similar points are equally distant from the plane of the roof. Representing the wall faces of a building

by the line DB (Fig. 111), and a section of the horizontal cornice by DBabcdef, Bab being the angle of the roof pitch; draw lines aa″, cc″, ff″, parallel to DB and intersecting the line ka″, which is drawn at right angles to DB through

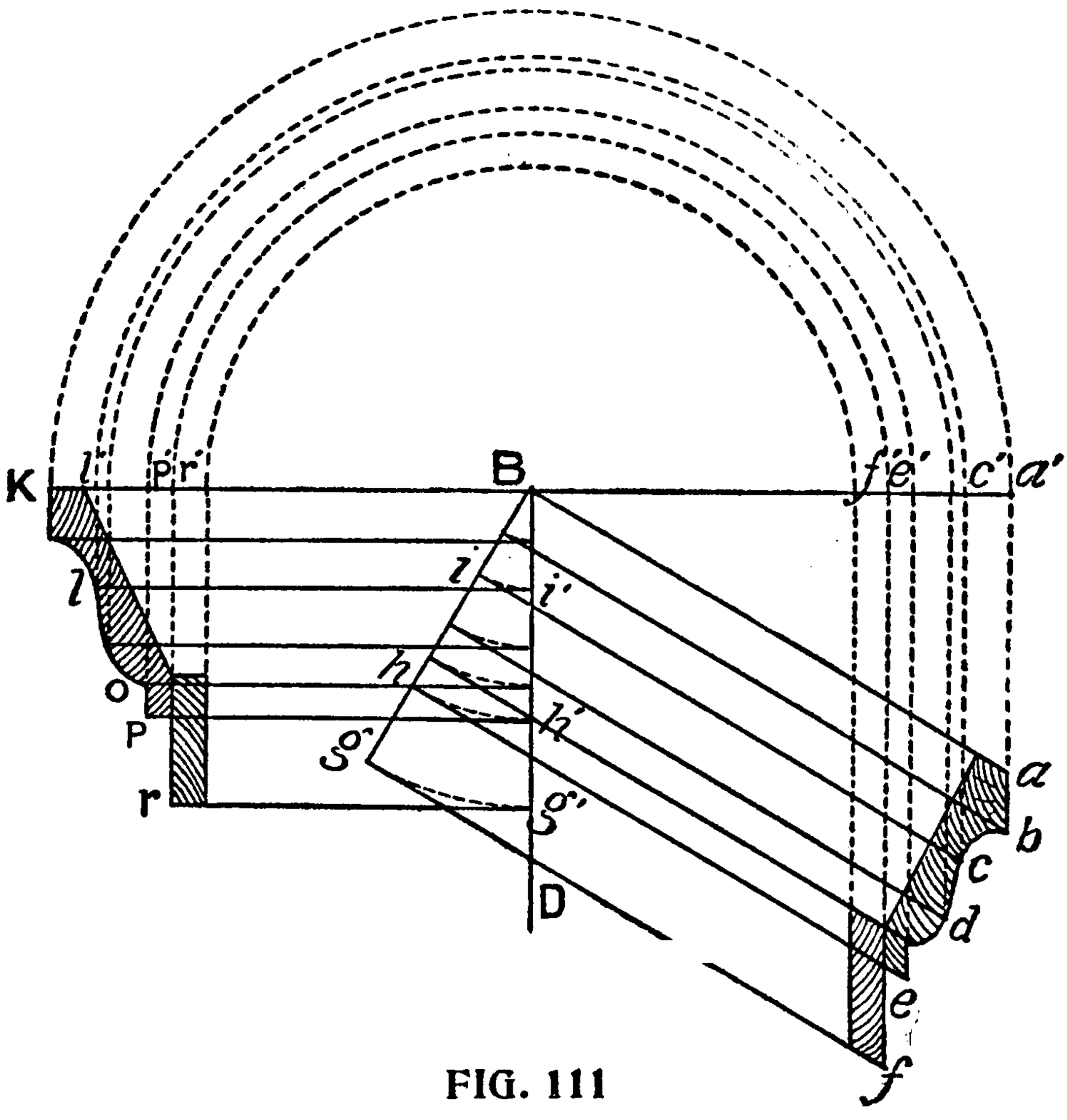

FIG. 111

the point B; then, with B as a centre, describe the arcs a″k, c″l″, etc., intersecting the same line ka″ on the opposite side of DB; after which extend lines from the points r″l″k, parallel to DB. This gives the point k at the same distance

from DB as the points a and a″, and the line ll″ at the same distance as cc″. The rest of the same group of parallel lines are found to be similarly situated with respect to DB.

From Descriptive Geometry we have the principle, that if we have given two intersecting lines contained in a plane, we know the position of that plane; hence we may represent the plane of a roof by the line Ba and Bk (Figs. 111 and 112); and since it will be most convenient to measure the distances required in a direction

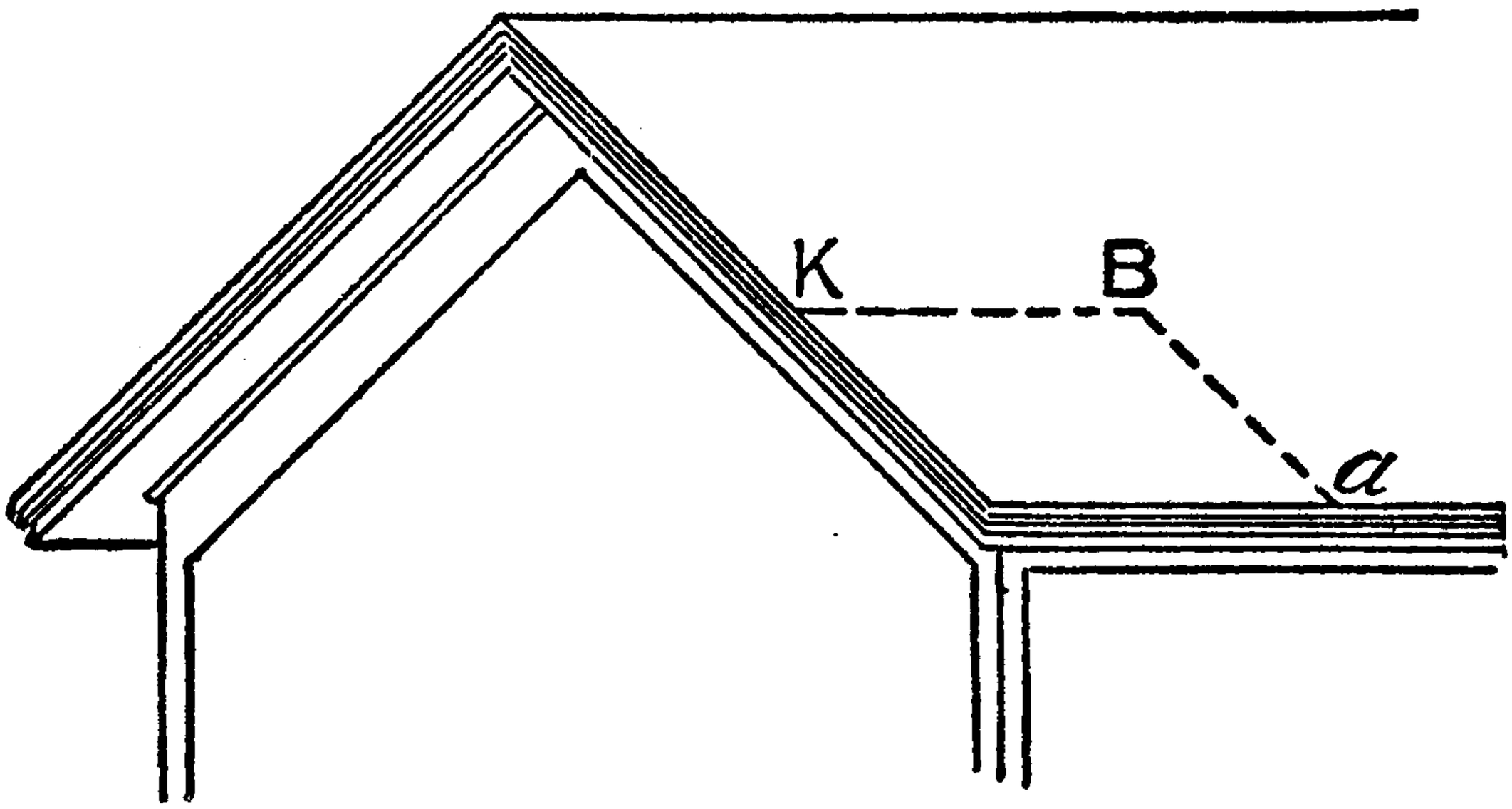

FIG. 112

perpendicular to that plane, in following out the principle draw lines from the points cef, etc., parallel to Ba and intersecting the line Bg, which is made perpendicular to Ba. This gives us on Bg the perpendicular distance of the points cef, etc., from the line Ba. From the intersections of these lines with Bg, and with B as a center, describe arcs intersecting the line DB at i″, h″,

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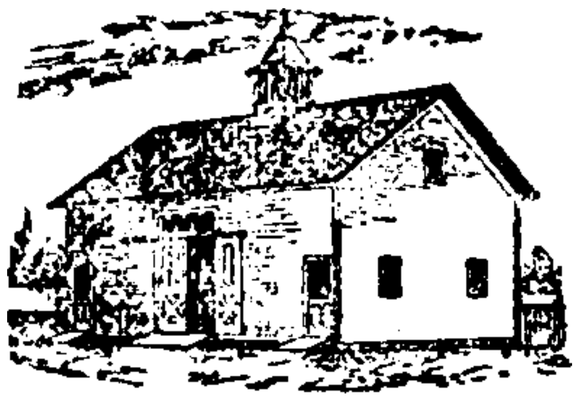
Take an ordinary plain miter box, NJL, and draw the line AB, making the angle ABJ equal to the pitch angle of the roof. Draw BD perpendicular to AB, and extend lines from B and E square across the box to K and C; join BC and EK. ABC will be the miter cut for two of the rake angles; HEK will be the cut for the other two angles, the angle HEN being equal to the angle ABJ. In mitering, both horizontal and rake moulding, that part of the moulding which is vertical when in its place on the cornice, must be placed against the side of the box.



Combination Squares

The ordinary steel square, fully treated of in the first part of this work, is, as has been clearly demonstrated, a constructive tool of wonderful possibilities in the hands of the skilful workman. The labor-saving tables and scales stamped upon the blade and tongue, as we have seen, furnish the workman with an ever-ready solution to almost any problem that may arise in roof framing or in laying out hoppers and hopper bevels.

But modern requirements have demanded even a more effective tool than this; and these requirements have been met by the ingenuity and inventiveness that have become proverbial as characteristic of the intelligent American workingman. The original steel square has been improved upon. Success in the builder's art to-day depends not so much upon the skill of the artisan as upon the superior quality of the tools he works with. Ingenious inventors, availing themselves of this fact, have placed at the disposal of American workmen certain improved forms of the steel square, with various time and labor-saving devices attached. These perfected tools are commonly known as "Combination Squares." Some of them do more than furnish the workman with a constructive tool of the highest excellence, seeming in fact literally to furnish him even with brains and an in-

creased number of hands, correspondingly enhancing the quality and quantity of his work.

Every workman, therefore, who uses the Steel

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the same time. The notches in the edge of the slot in the blade are $\frac{1}{8}$ of an inch apart, and are to enable it to be conveniently used as a gauge. To use the bevel, loosen the clamping bolt, draw the protractor out to the angle required, and clamp in place. Set the protractor by the scale marked on the circular segment. This scale is marked to indicate the angle expressed in inches rise for twelve inches base, when set on the figure 6, in the first series. The angle is one which will give rise of six inches in twelve, or the angle for the bottom of rafter $\frac{1}{4}$ pitch. Set on the 6 in the second series and you have the angle for the top of the rafter for the same pitch. So with all the figures in the first two series. The first series is from 1 to 12, the second from 12 to 1. The third series is for convenience, when it is not convenient to turn the tool over to get reverse angle. The circular segment is laid off in degrees on the lower side, which will readily show you the figures on a square with 12 required to cut any desired number of degrees. The notch in the end of the protractor will enable the tool to be used for a gauge to get in corners, guaging for setting hinges and beveling edges, etc.

Ideal Bevel Try-Square.—This tool, shown in Fig. 113c, is a combination of a bevel and a try-square. The inventor of the tool claims that by using it a carpenter can accomplish more than ordinarily in laying off work. (1) He can mark the square and bevel cut with one continuous stroke of pencil without having to change square.

(2) It is easy to change the bevel blade to any angle, as the slot in the bevel blade will allow shifting so it will always come to corner of square blade. (3) By setting bevel at right angle to

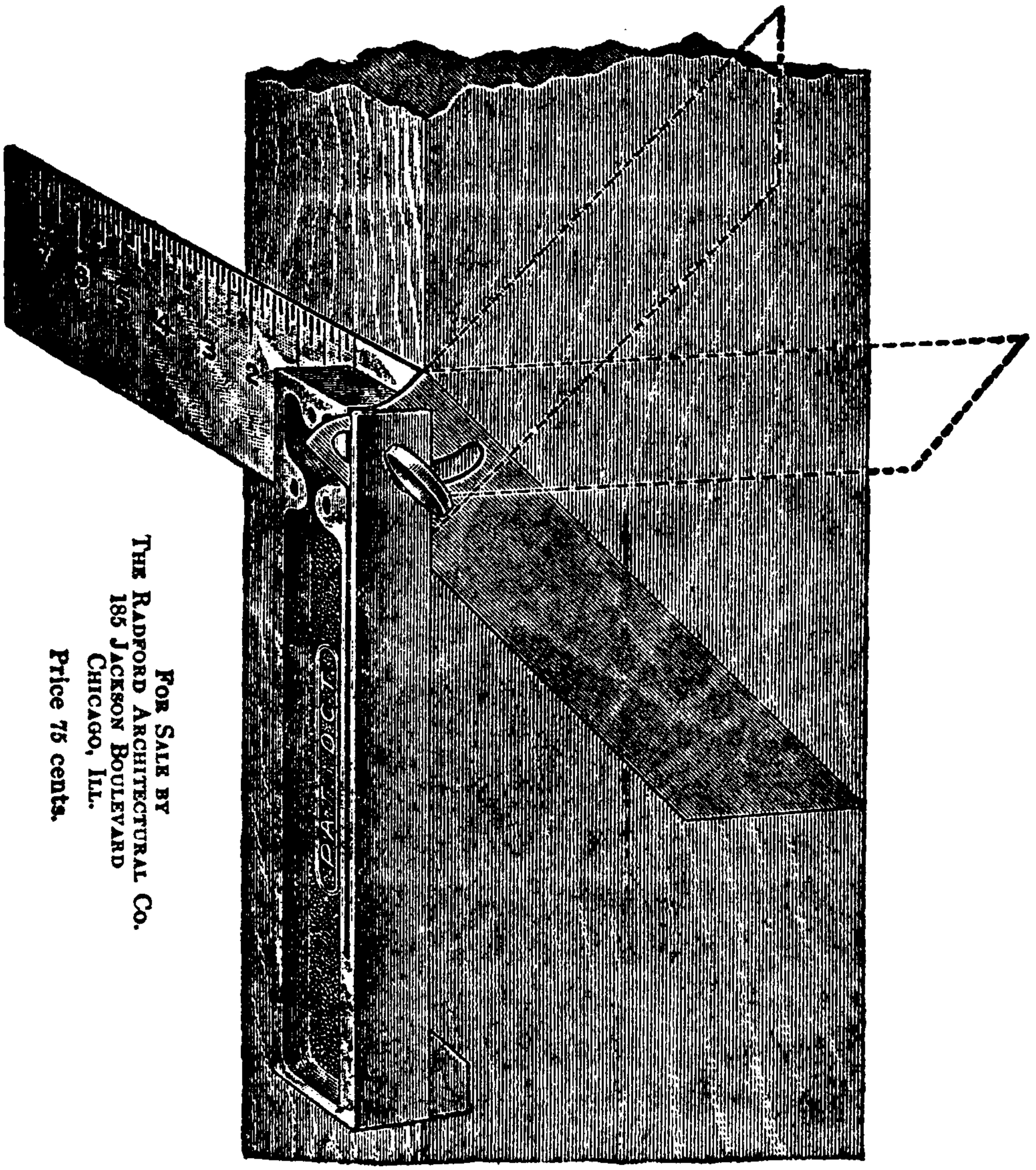

FIG. 113C

Try Square blade, both marks can be obtained without changing the position of square. (4) For beveling a board on edge, swing bevel blade over

to back of handle, which gives a straight surface on handle. (5) When bevel blade is not needed, close same in handle, and you then have a regular Try Square. (6) The Try Square blade is graded in eighths, and the figures are stamped very plain. All parts, it is claimed, are made of the best steel, except the handle, which is of a composition metal that will not rust.

Topp's Framing Tool.—Is a very ingenius combination square, consisting of a T square, a try

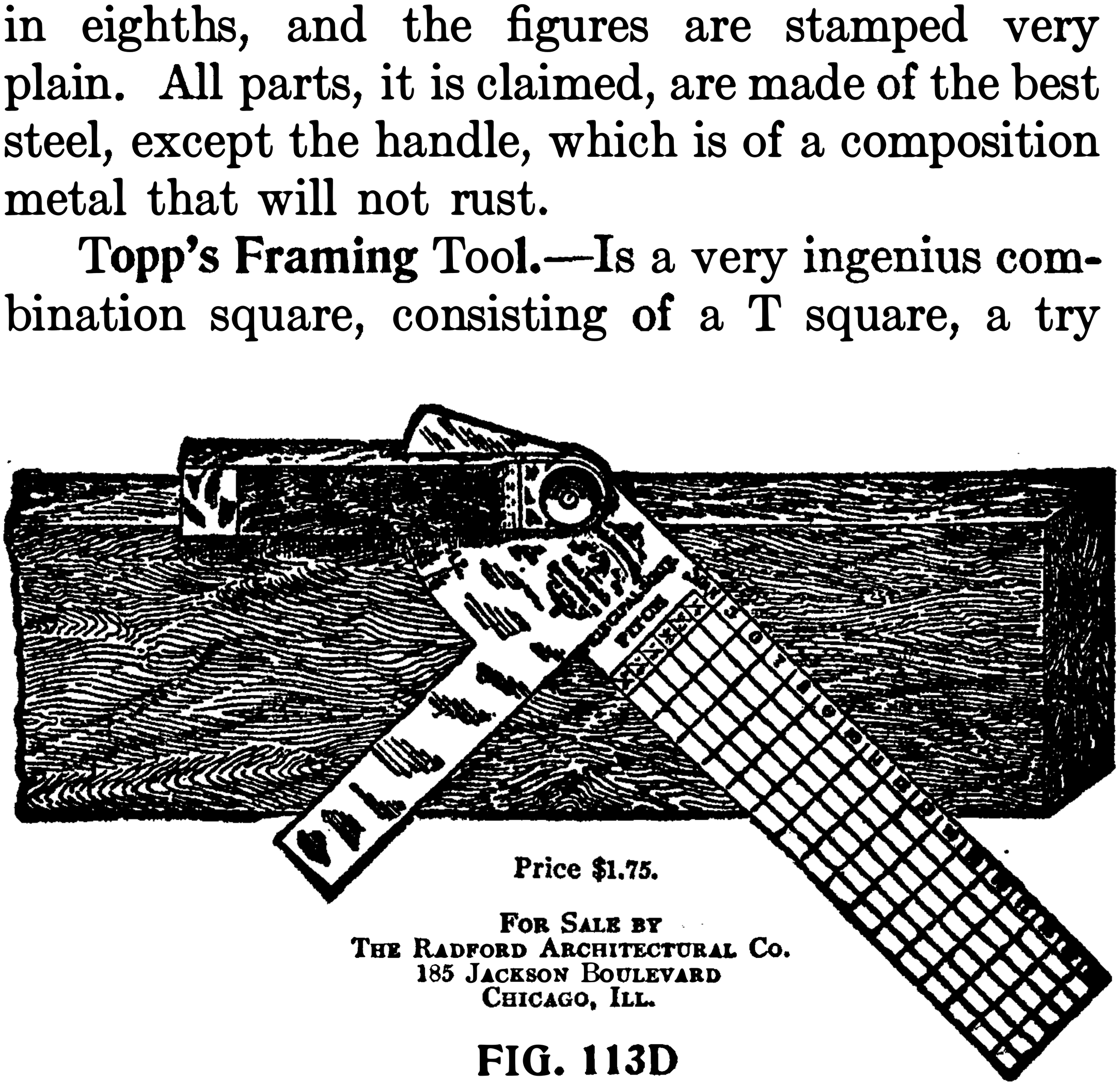

FIG. 113D

square, and a bevel square. It gives all the cuts for different pitches on all kinds of rafters, and the lengths of same, for any plan. Fig. 113d shows the manner in which this tool is used when marking out rafters.

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country. It is of celluloid, three inches in diameter, on either side of which is pivoted at the center a disk, one side giving the lengths and cuts for the common rafter, having a rise from 1 to 24 inches to the foot, also the corresponding lengths, cuts, and bevels for the octagon hip or valley, and for the hip or valley resting on the right angled corner, while on the other side is given the seat and plumb cuts for rafters and braces having a rise from 1 degree to 90 degrees. It also gives the length of sides and miter cuts for all regular polygons, or the framing of timbers at any degree, and shows how to apply the steel square to obtain the cuts.

The Rafter Table.—Fig. 114 illustrates the side containing the rafter table; it is divided into twenty-four sections, radiating to a common center. These sections represent from 1 to 24 inches rise to the foot in run. The first figures represent the rise, and the three following sets of decimal numbers represent the lengths in inches of the common rafter, octagonal hip and the common hip or valley rafter respectively. The heavy-faced fractional numbers designate the pitch or proportion of the rise of the roof to a foot run, while just beneath the fractional numbers is given the same value in decimal fractions to the one-hundredth part of an inch. The latter is placed here for convenience in finding the near equivalent in common fractions for the decimal part of an inch.

The Revolving Disk contains the title and

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and the blade the plumb cut for the common rafter.

For the Corresponding Octagon Hip and the Common Hip or Valley substitute 13 and 17 on the tongue respectively, the tongue always giving the seat cut and the blade the plumb cut. The lengths of the rafters for a one-foot run are found to be 14.42, 15.26, and 18.79 for the common rafter, octagon hip and common hip or valley, respectively. Having the lengths given for one foot in run, it is an easy matter to find the lengths of the rafters for any run in either feet or inches by multiplying the lengths here given by the number of feet or fractions of a foot in the run, and point off as many places in the product as there are decimal figures used in the solution, and reduce to feet and inches. Fractional figures may be avoided in the run by dropping them and finding the length only for the number of feet, and then from the plumb cut measure square out the amount of the fraction, which will give the point for the proper plumb cut.

To Find the Common Difference in the Length of Jacks multiply the length of the common rafter (14.42) by the number of inches in the spacing, and divide by 12. Thus, if the jacks be placed 16 inches on centers, 14.42x16=230.72; divide by 12=19 and two-twelfths inches.

To Find the Common Difference for the Octagon Jack multiply 14.42 by 2.4, and the product by the spacing, and divide by 12. Thus: 14.42 x2.4=

34.608 x 16=553.728 divide by 12=46 and one-twelfth inches.

For the Side Cut of the Jack.—Take 12 on the tongue and 14.42 (14 and five-twelfths) on the blade. The blade will give the desired cut.

For the Side Cut of the Octagon Jack.—Take 5 on the tongue (because 5 is practically equal to the side of an octagon when the diameter is one foot) and 14 and five-twelfths on the blade, the blade giving the cut.

The figures that give the side cut of the jacks in either of the above cases will also give the cut across the face of the roof boards to fit in the valley or over the hip. The tongue gives the cut.

For the Side Cut of the Hip or Valley.—Take 17 on the tongue and 18.79 (18 and 19-24) on the blade, the blade giving the cut. Backing of the hip. Take 8 on the tongue and 18.79 on the blade. The tongue will give the required bevel. A quicker way, however, is to set off ½ the thickness of the hip along the line of the seat cut (or a line parallel with it), which will give the gauge point from which to remove the wood to the center of the back of the hip. The backing for the octagon hip is practically one-half of that for a hip resting on a square corner.

Table of Tangents.—Fig. 114a represents the table of tangents.

The figures in the two circles represent the degree. Those in the inner circle represent the tangents, and those in the outer represent the

co-tangents, the sum of the two always equaling 90 degrees.

The set number is in either case 12 on the tongue and tangents on the blade. The blade

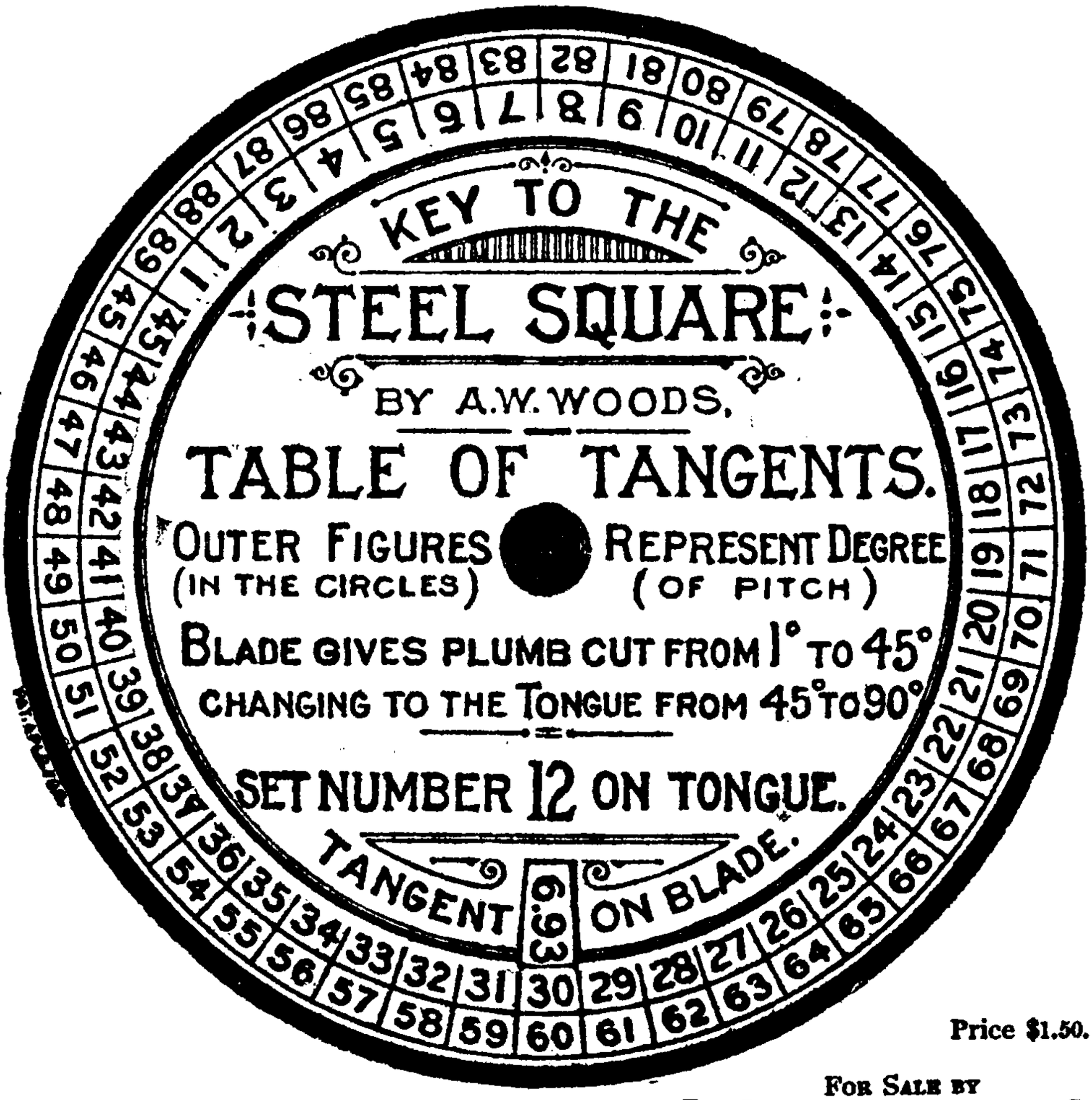

FIG. 114A

gives the cut up to 45 degrees, then it reverses to the tongue from 45 degrees to 90 degrees.

Example: To Frame a Roof With 30 Degrees Pitch.—Operations: Turn the slot till it rests opposite 30 degrees and you have, as shown in **Fig. 114b:**

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on the blade. The blade will give the cut. Side cut of octagon jack. Take 5 on the tongue and proceed as for the common jack

Side Cut of Hip or Valley.—Take 17 on the

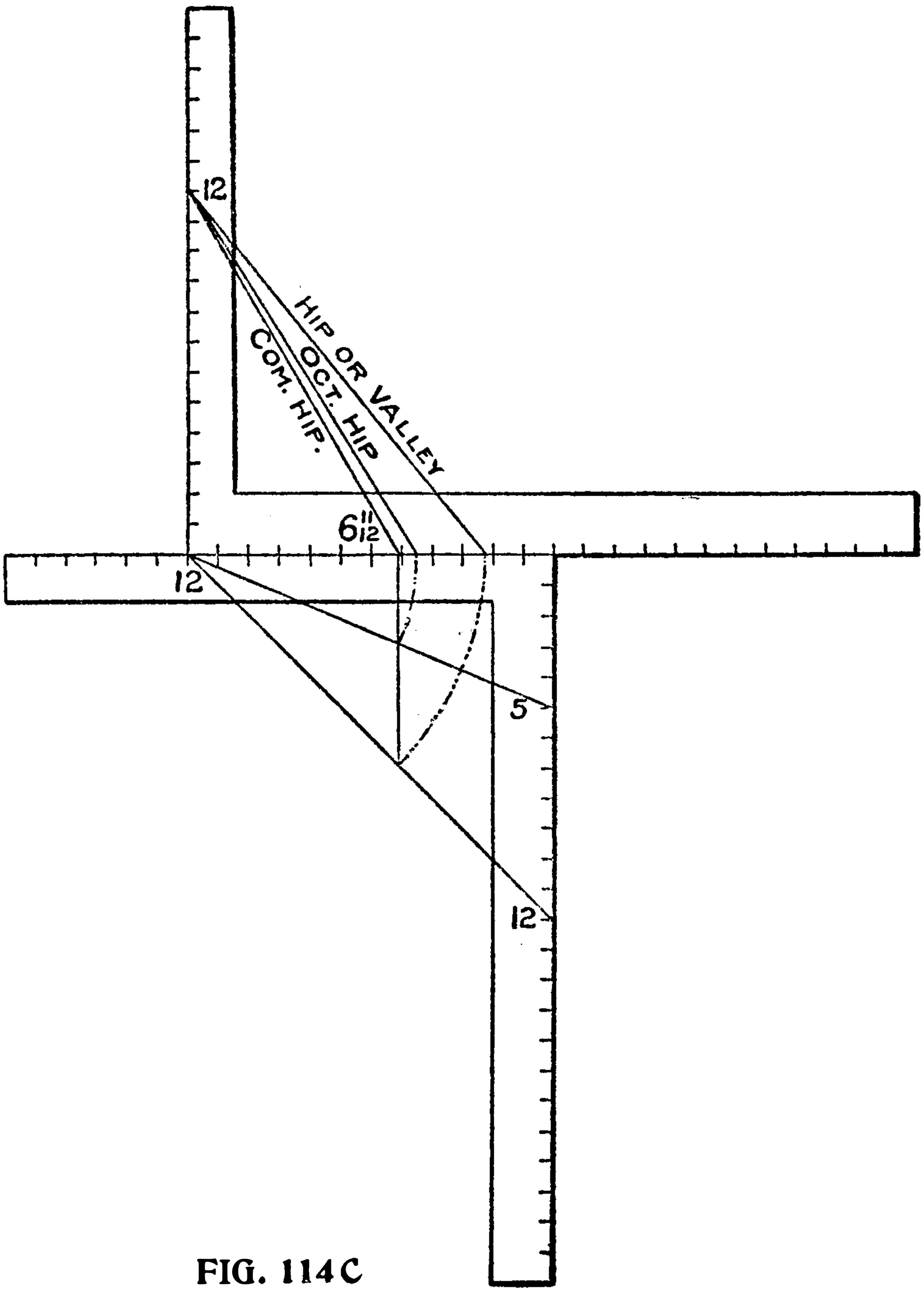

FIG. 114C

tongue and the length from 17 to 6 and 11-12 taken on the blade. The blade will give the cut. If the roof be 60 degrees pitch proceed the same as for the 30 degrees pitch (using the same figures), but the cuts are reversed on the square. However, this only applies to the seat and plumb cuts of the common rafter. The same may be

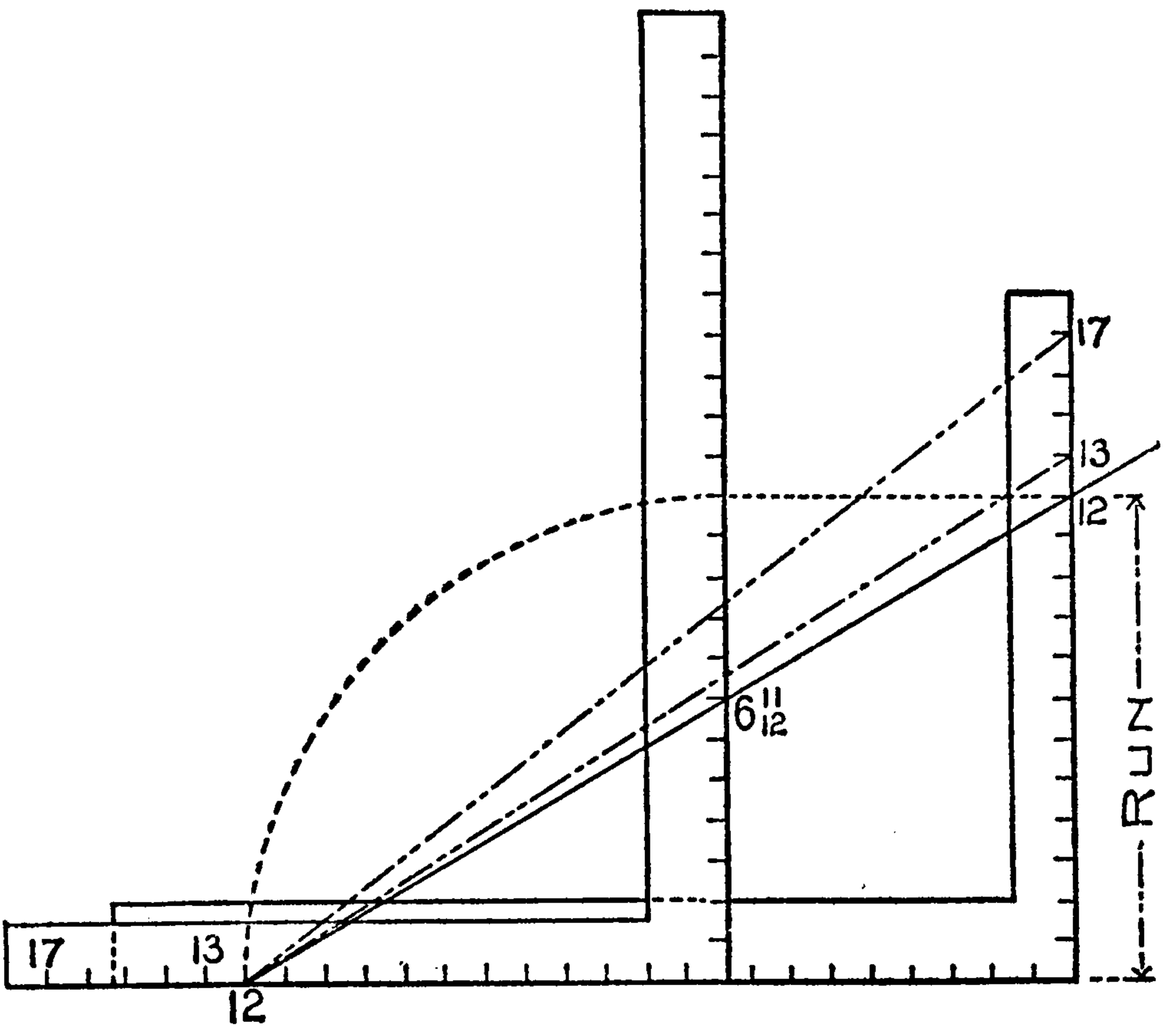

FIG. 114 D

obtained for the hips, as shown in Fig. 114c, but the lengths of the rafters are not so readily obtained as before because what was the run is now the rise. To get the lengths by scale it is necessary to extend the pitch lines till the base

or run of the common rafter equals 12 inches, as shown in Fig. 114d.

To **Find the Miter for Any Regular Polygon.**—Divide 180 by the number of sides in the polygon.

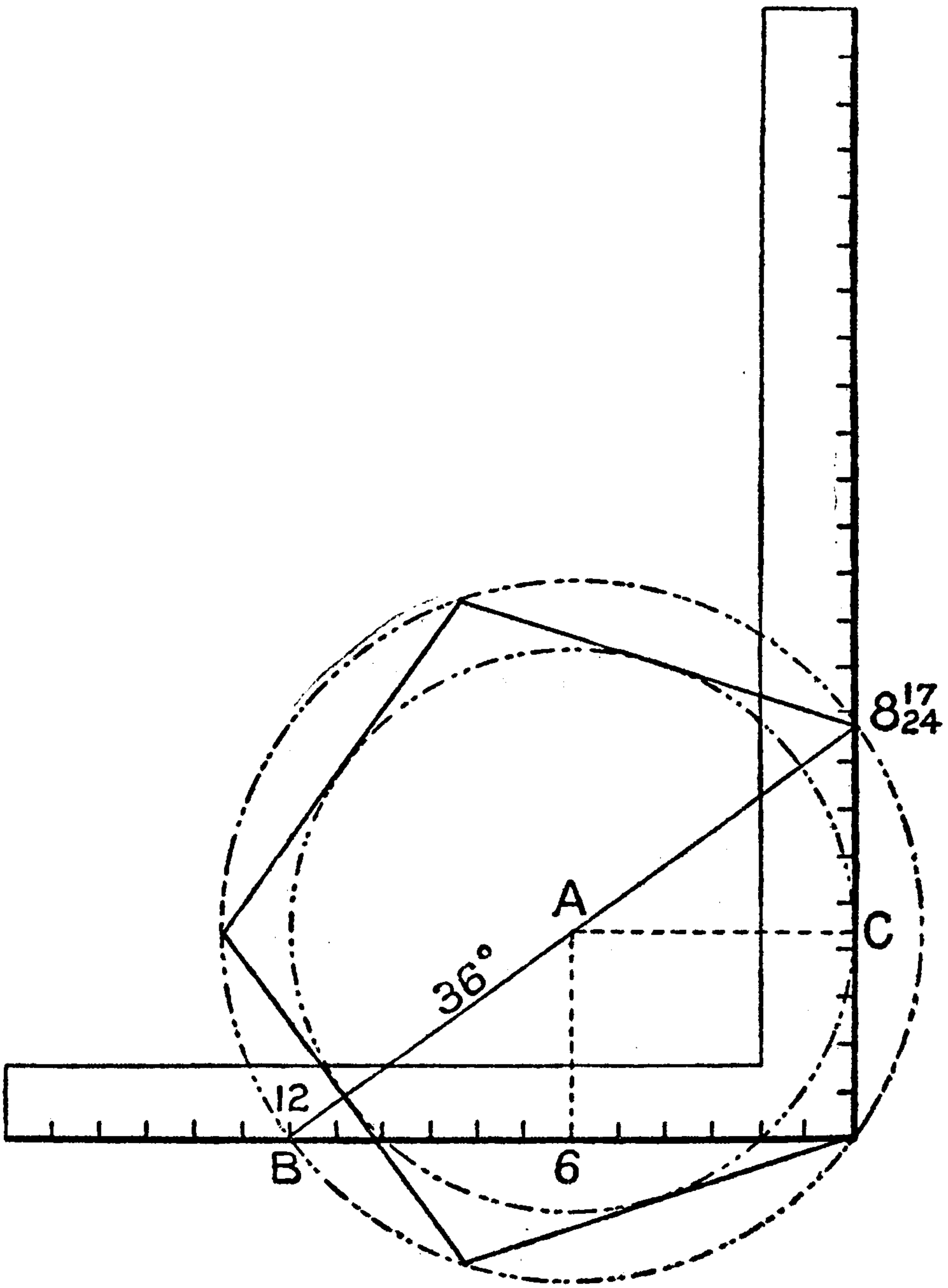

FIG. 115

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If we let 8 and 17-24 act as a pivot as shown in Fig. 115 and swing the blade till it rests along the 36 degree line, it will show as in Fig. 115a. The 12 on the tongue will rest in line with one of the sides of the pentagon and the blade will rest along the line of the miter, thus proving that the latter gives the cut. The figures 8 and 17-24 also represent the length of one of the sides when the inscribed diameter is one foot.

Polygons of any size may be drawn as shown in Fig. 115b. However, it is better to multiply

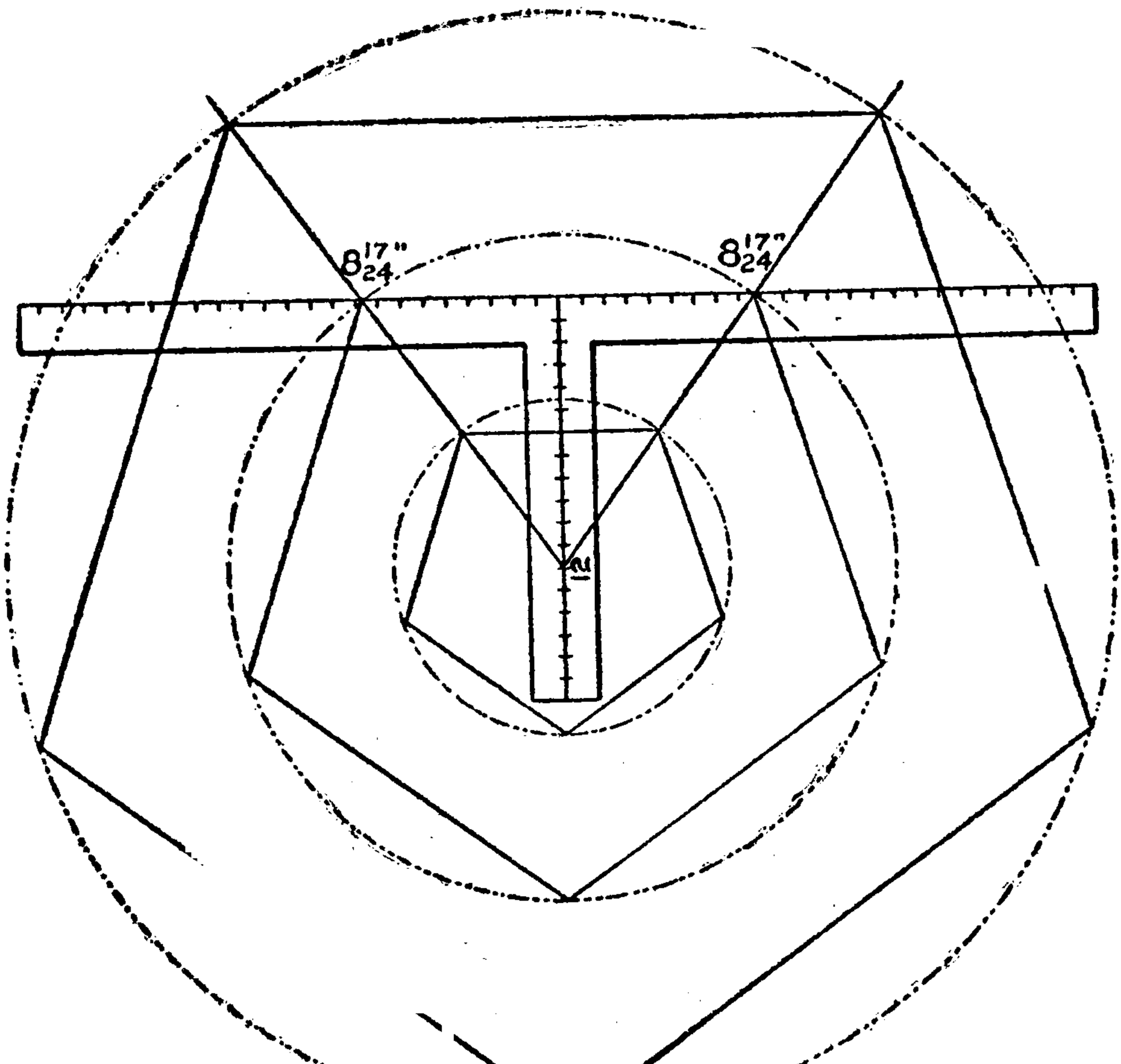

FIG. 115B

the desired diameter by the decimal number given and reduce to feet and inches as follows: Suppose we wish to make a pentagon frame ten feet inscribed diameter, 10x8.72=87.20 inches, or

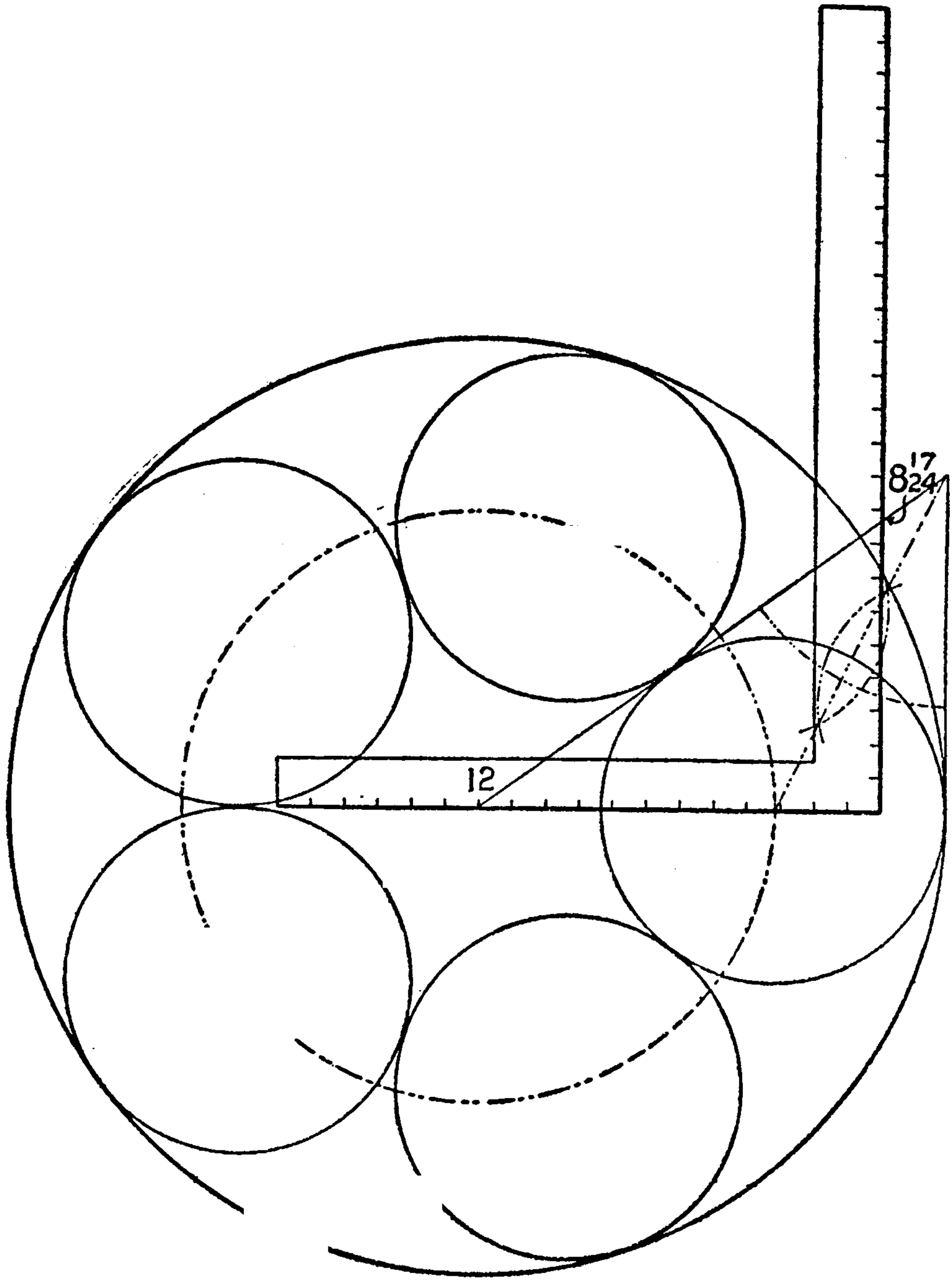

FIG. 115C

7 feet 3 and 5–24 inches will be the length of the sides. If we wish to put five circles inside of a large circle it may be done as shown in Fig. 115c. The given circle may be of any size and the figures used on the steel square are the same as those used in the preceding illustrations. From this it will be seen that it is the degree line that governs the layout of the diagram. If we wish to put four circles inside of a given circle then the degree

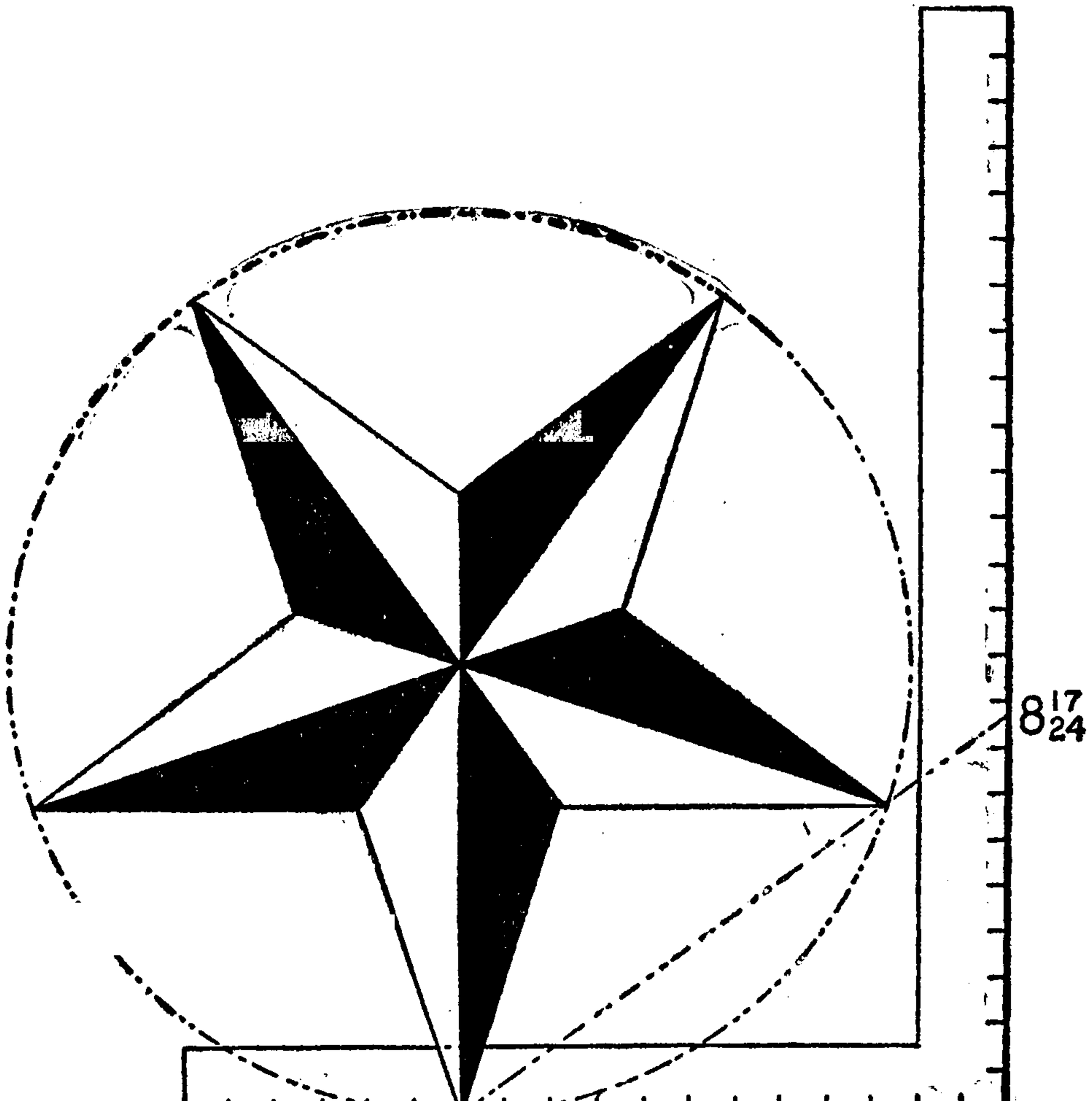

FIG. 116

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To Frame Timbers at Any Degree of Pitch.—Frame two pieces at an angle of 110 degrees. It is evident that the miter should stand at half way between the angle, or at 55 degrees; and 55 degrees from 90 degrees leaves 35 degrees, and we find the tangent for 35 degrees is 8.4 (=8 and 5-12). Therefore, 12 on the tongue and 8 5-12

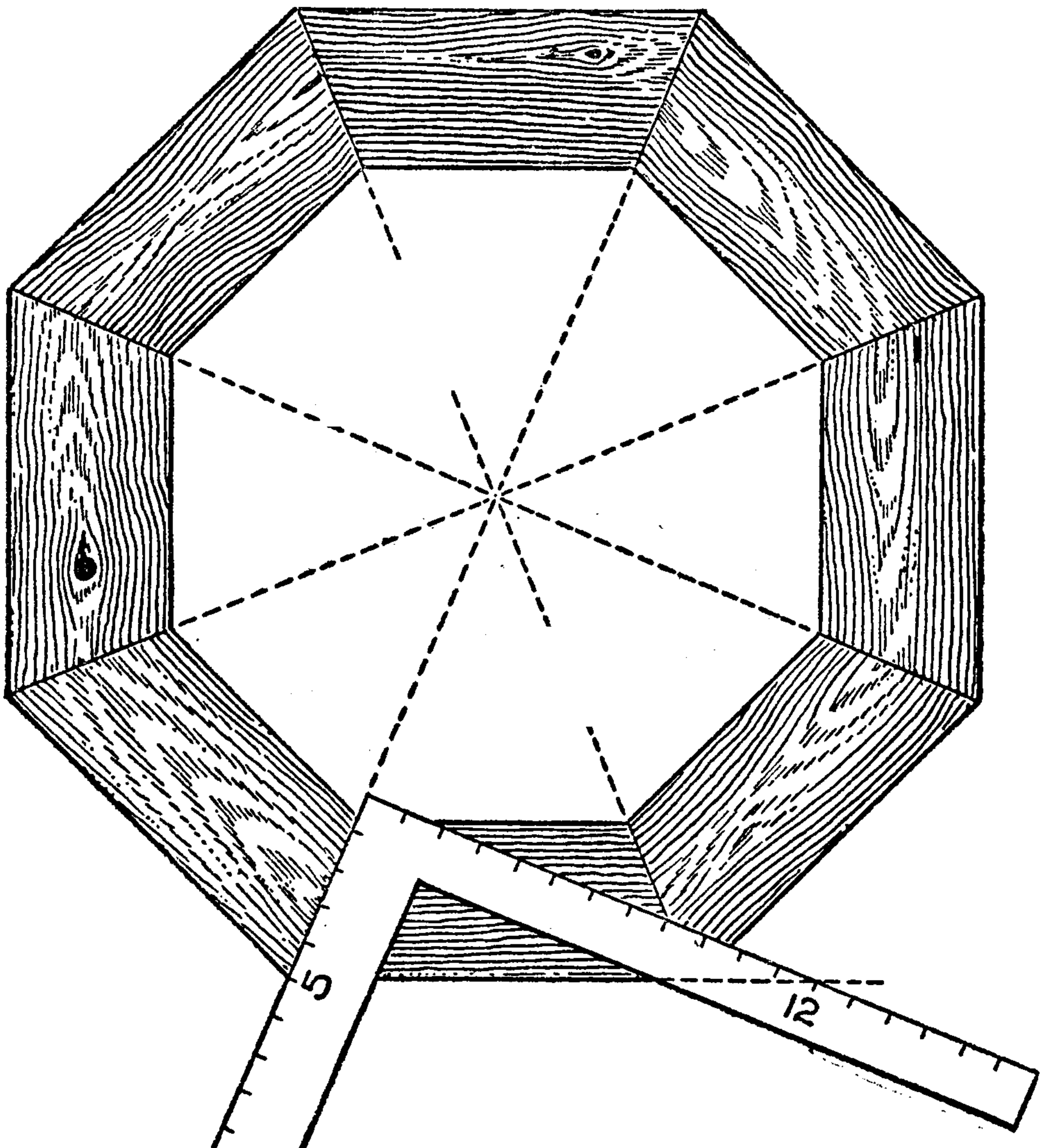

FIG. 116 B

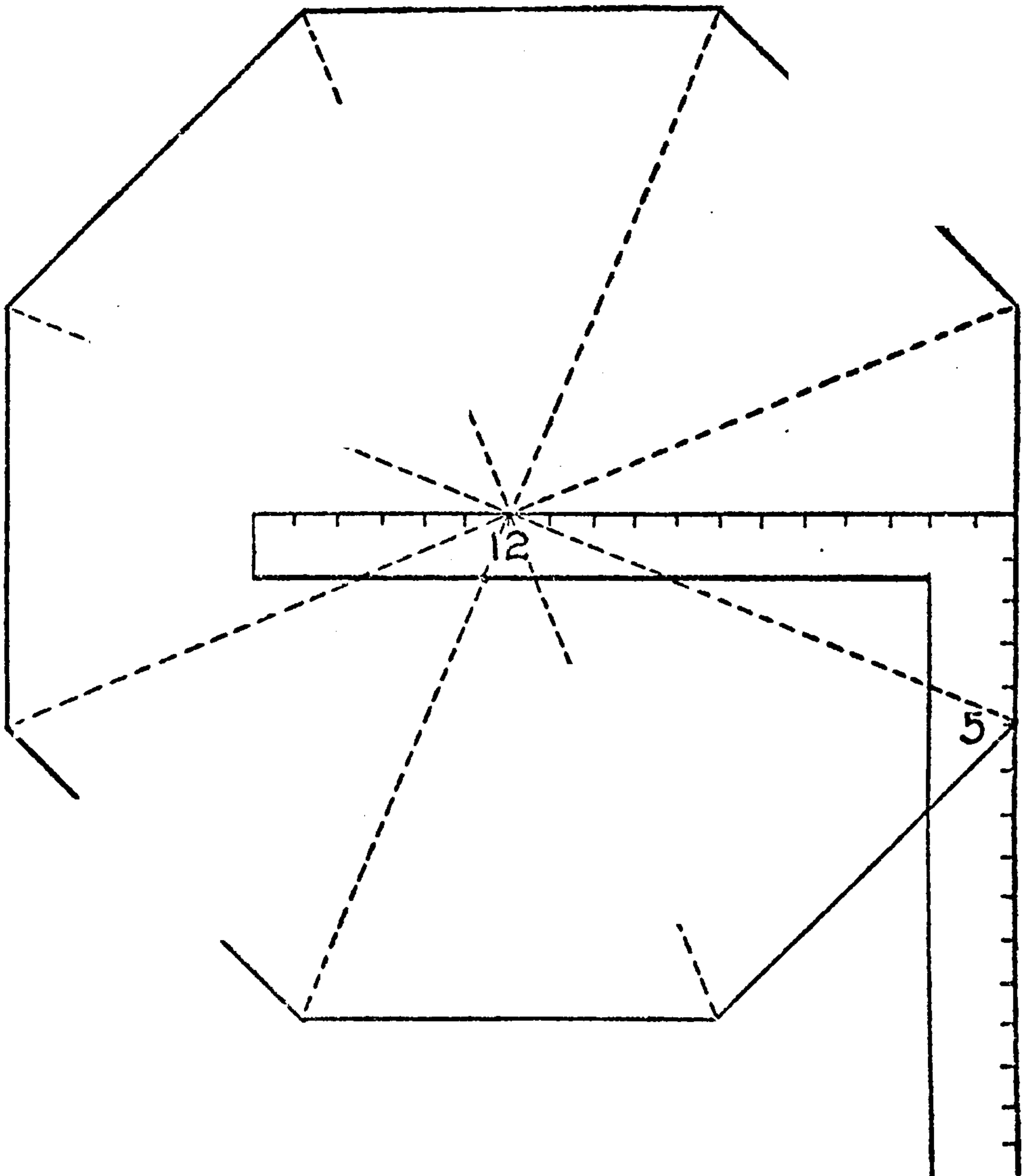

FIG. 117

on the blade will give the miter, the blade giving the cut, as shown in Fig. 116a.

Though it may seem that some of these problems are of but little value on account of the small demand for their use, yet to know how to correctly handle the simpler forms is to know them all. It is true that the carpenter is not often called upon to frame polygonal roofs other than for the square or octagon shape, yet to be able to do so makes him a more finished and competent workman.

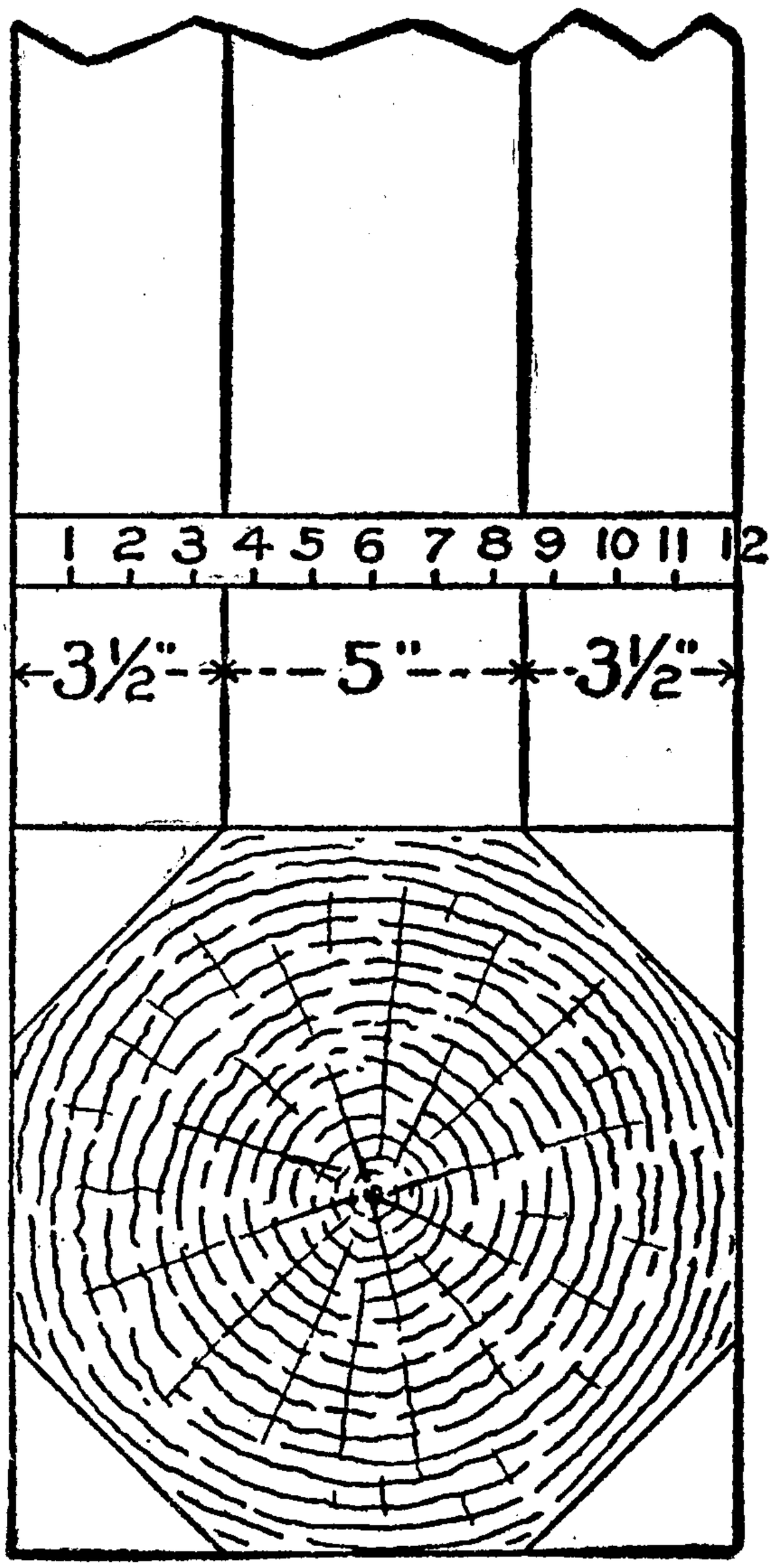

FIG. 117 A

The Octagon for an Example.—With this in view we will take the octagon for an example; we have found that 12 and 5 taken on the tongue and blade of the square give the miter as shown in Fig. 116 B. These figures also form the angle that the hip rests with the common rafter as shown in Fig. 117. They also form the basis for all of the cuts. We also find for the true octagon

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the run of the hip diverges from the tongue 5 inches in a one foot run. Hence the side of an octagon one foot in diameter must be 5 inches at shown in Fig. 117A, or five-twelfths of its diameter. This proportion always exists whether it be inches, feet or yards. Thus the side of an octogan one inch in diameter would be five-twelfths of an inch. A 6-inch diameter would be 6x5-12= 30-12 or 2½ inches, as shown in Fig. 117b.

Again from 12 to 5 measures 13 inches, a gain of one inch to one foot run of the common rafter, therefore the run of an octagon hip is one-twelfth longer than that of the common rafter.

The Curve for an Octagon Hip.—Now let us apply this proportion in developing the curve for an octagon hip.

In Fig. 117c draw BA. Place the square as shown, and draw line AC, and square down from B to C. AB is the run of the common rafter. A C is the run of the hip, and is one-twelfth longer than AB; BC is equal to one-half the length of the plate, and is five-twelfths of the length AB. The whole figure bounded by A, B and C,

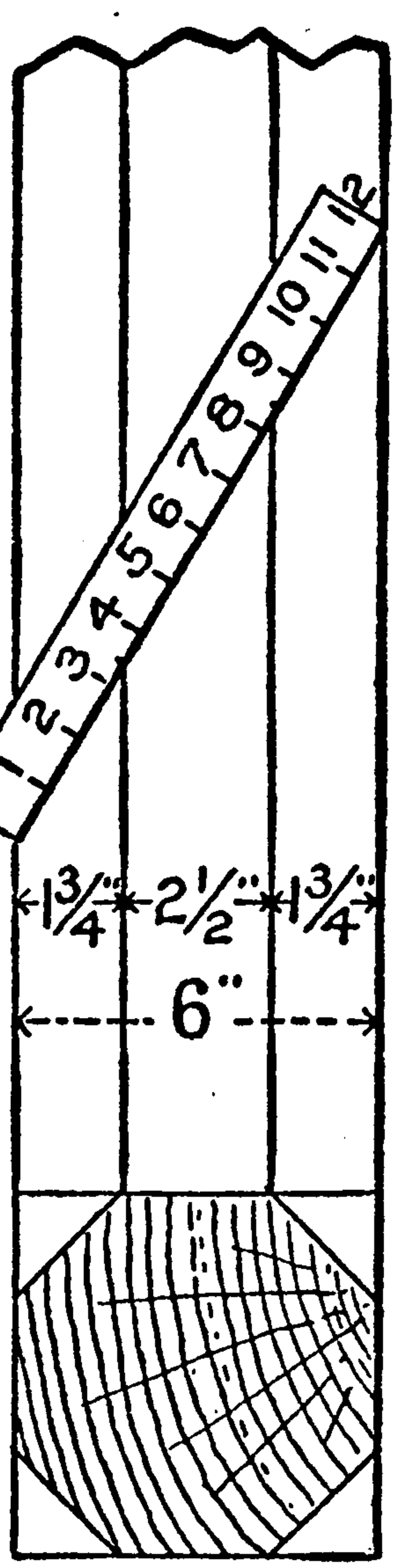

FIG. 117B

is one-sixteenth of the plan, and is all that is necessary to draw.

Now, lay off the rise AD, and the desired curve

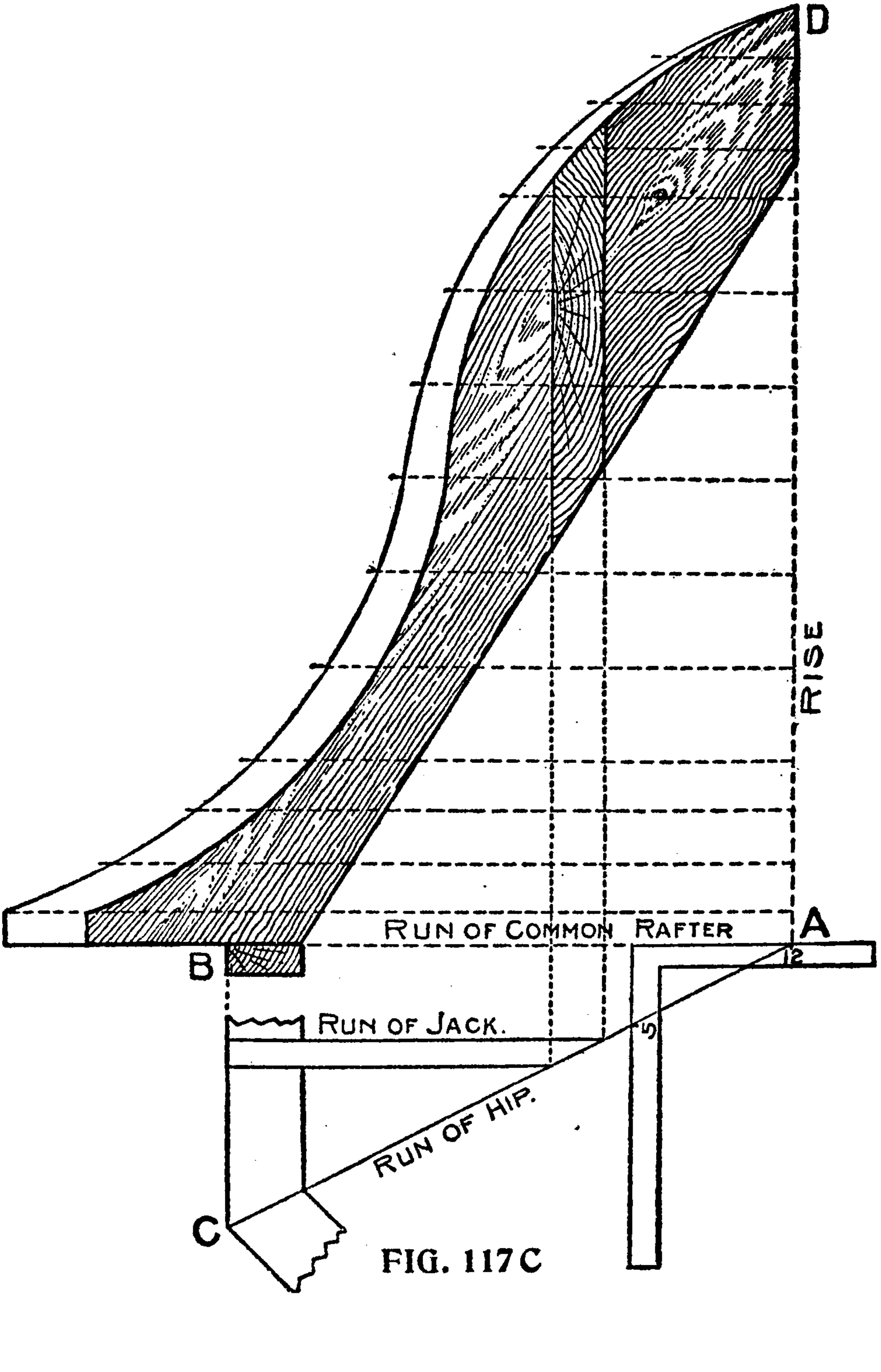

FIG. 117C

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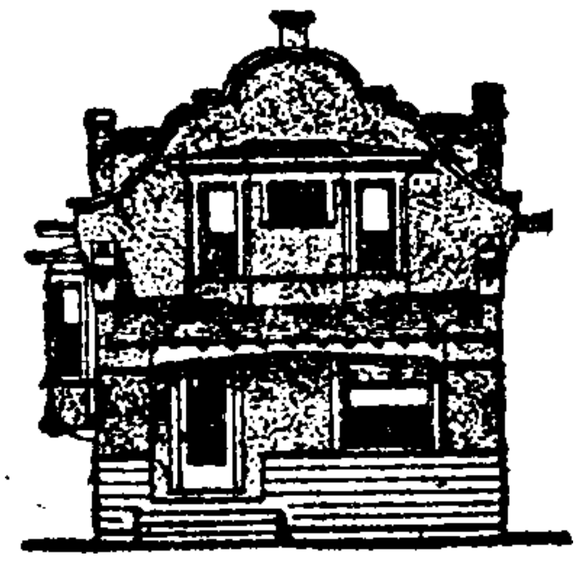
measured, run an off hand curve through the dots, and the corresponding hip is determined.

To Find Shape of Jack.—The jack being a part of the common rafter, its shape is easily found by laying off the run and squaring up as shown.

It is thought better to run only the hips to center, and by using an octagon-shaped block or pole set with the sides, so that the hip will rest against it squarely, so as to get good nailing, as shown in Fig. 117d; besides letting the block extend above roof, furnishes an excellent stay for a finial.

To Find the Backing for a Curved Hip, measure back from the face, on the horizontal lines, one-half the thickness of the hip and run an off hand curve, as previously done for the face line, and this will be the proper gauge line along the side of the hip. It is very important that the hips should be backed in roofs of this kind, because the shape is ever changing and the backing should correspond.



Possibilities of the Steel Square

It is doubtful if even carpenters themselves generally recognize what a wide range of possibilities lie in the steel square. This instrument may truthfully be said to be the **one great tool** of the carpenter. The cutting edge, or knife, may be older; but no other tool is of greater value or capable of wider application.

What may not be accomplished with the aid of the steel square in the construction of useful and ornamental diagrams, would indeed be a hard question to answer. It is safe to say that there can be no tool devised that will ever supersede the steel square in covering so wide a range in the various construction arts. It is all contained in the simple scale of measure in connection with the 90 degrees formed by the arms of the steel square, ready to solve the most intricate problems when knowingly handled by the operator.

In presenting these illustrations, it is our aim to put them in such a way that the reader will readily understand the principles involved, so that they may be intelligently reproduced, and thereby assist in opening up the way for much useful information.

Polygon Family Circle.—In Fig. 118 is shown the polygon family circle. In this, we show

eight of the polygons enclosed in a circle, the center of which may be at a point anywhere on a perpendicular line above twelve on the tongue of the steel square. In this case it is taken at nine inches above, thereby giving a circle of eighteen inches in diameter. Where the circle cuts the miter lines, as from 12 to A of the triangle, will be the length of one of the sides and from which the others may be spaced. The

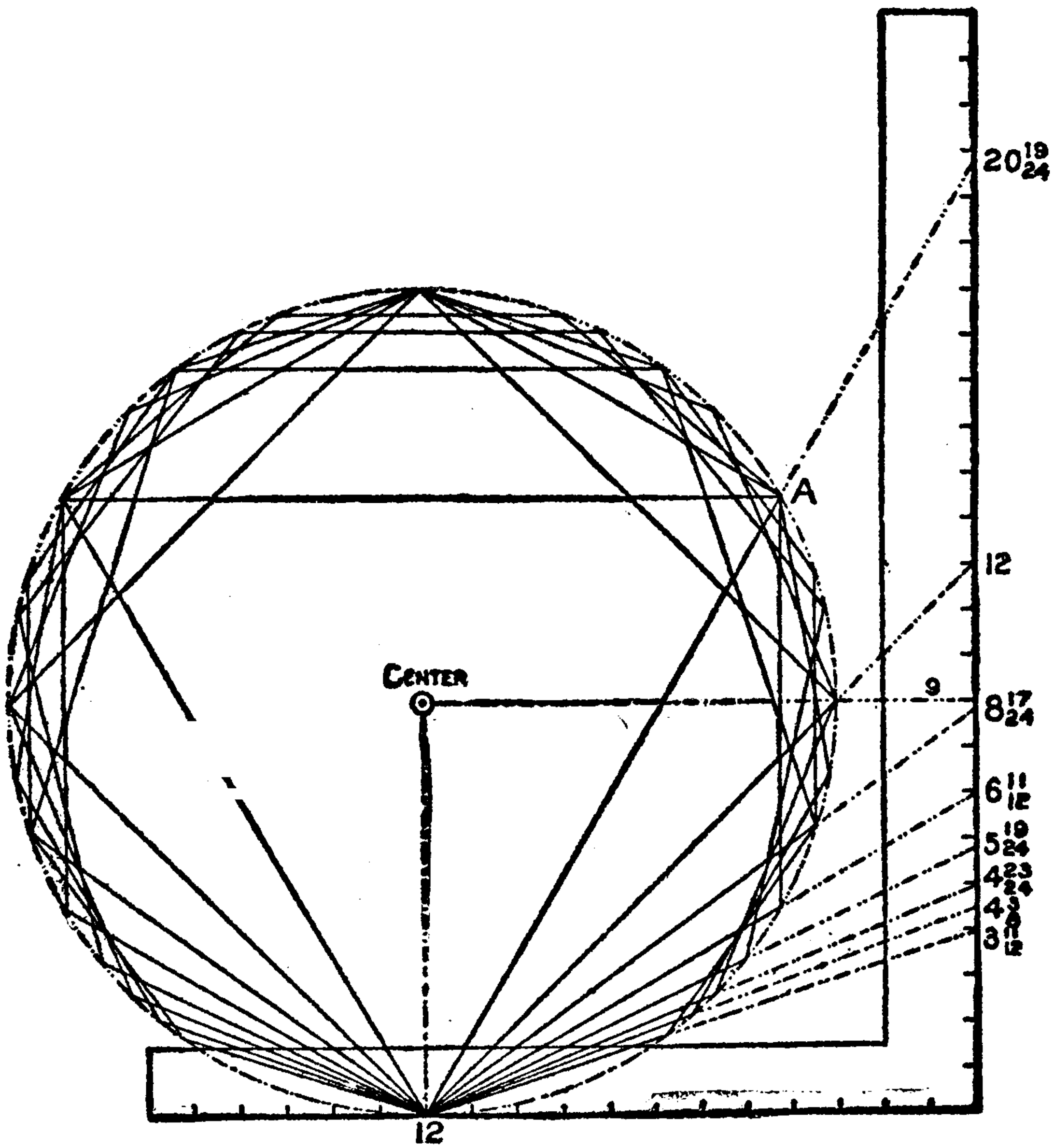


FIG. 118

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the polygons are determined from the heel of the steel square to the intersection of the miter lines with the circle as from the heel to A and B for the square and octagon respectively.

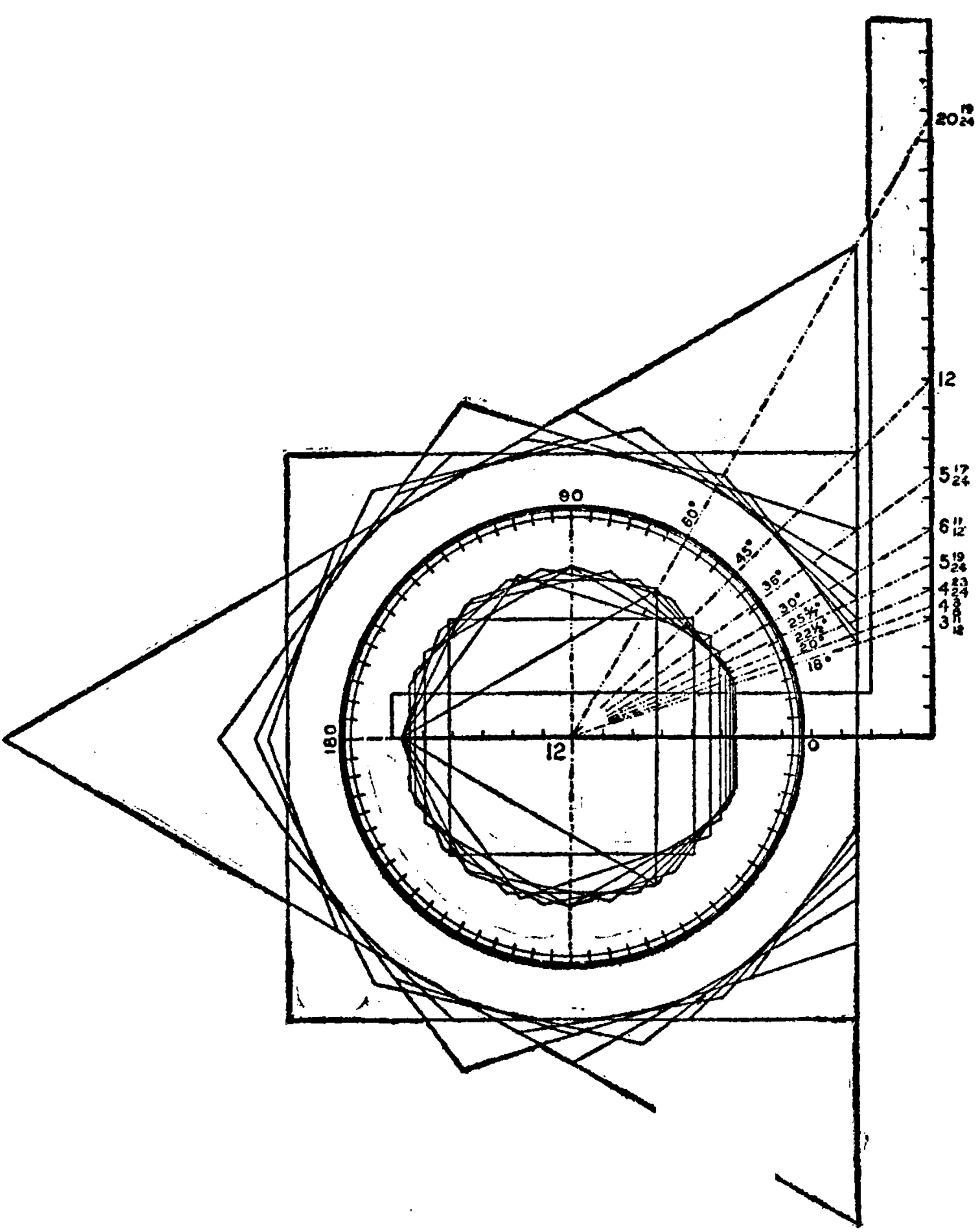

FIG. 120

In Fig. 120 are shown two sets of polygons in connection with the degrees and according to

the scale, the inner set is drawn to a circumscribed diameter of one foot, while the outer set is drawn to an inscribed diameter of nineteen inches. The starting point in either case is at midway of the sides of the polygons, and the more drawn, the more nearly a true circle they will form. In the former, the corners form the circle and in the latter the central part of the sides lends to the shaping of the circle.

In Fig. 121 are shown the polygon circles. In this illustration each polygon has its individual circle. Beginning with the triangle we show the miter lines for eight of the polygons and by squaring up from 6 on the tongue and at the intersections with the miter lines determine the center of the circles. The reader will notice that each circle cuts at three points on the steel square, also notice the dropping down of the circles and the shadows they cast at the two lower points of the steel square. At first glance it might appear that the circles are not true, but a more careful inspection would show that they are as true as can be described with the compass. The descent of these circles from the triangle down to the decagon is quite rapid, but from this on down it would be a very different thing. The miter lines of a polygon having 180 sides would intersect the blade at one degree, or .21 (5-24) which is less than one-fourth of an inch, and would be the length of the sides of the polygon with an inscribed diameter of one foot. The miter line for a polygon having 360 sides would intersect the blade at

.10476. From this it would appear that the continued increase of the sides of a polygon of this size would become too short to be discernible,

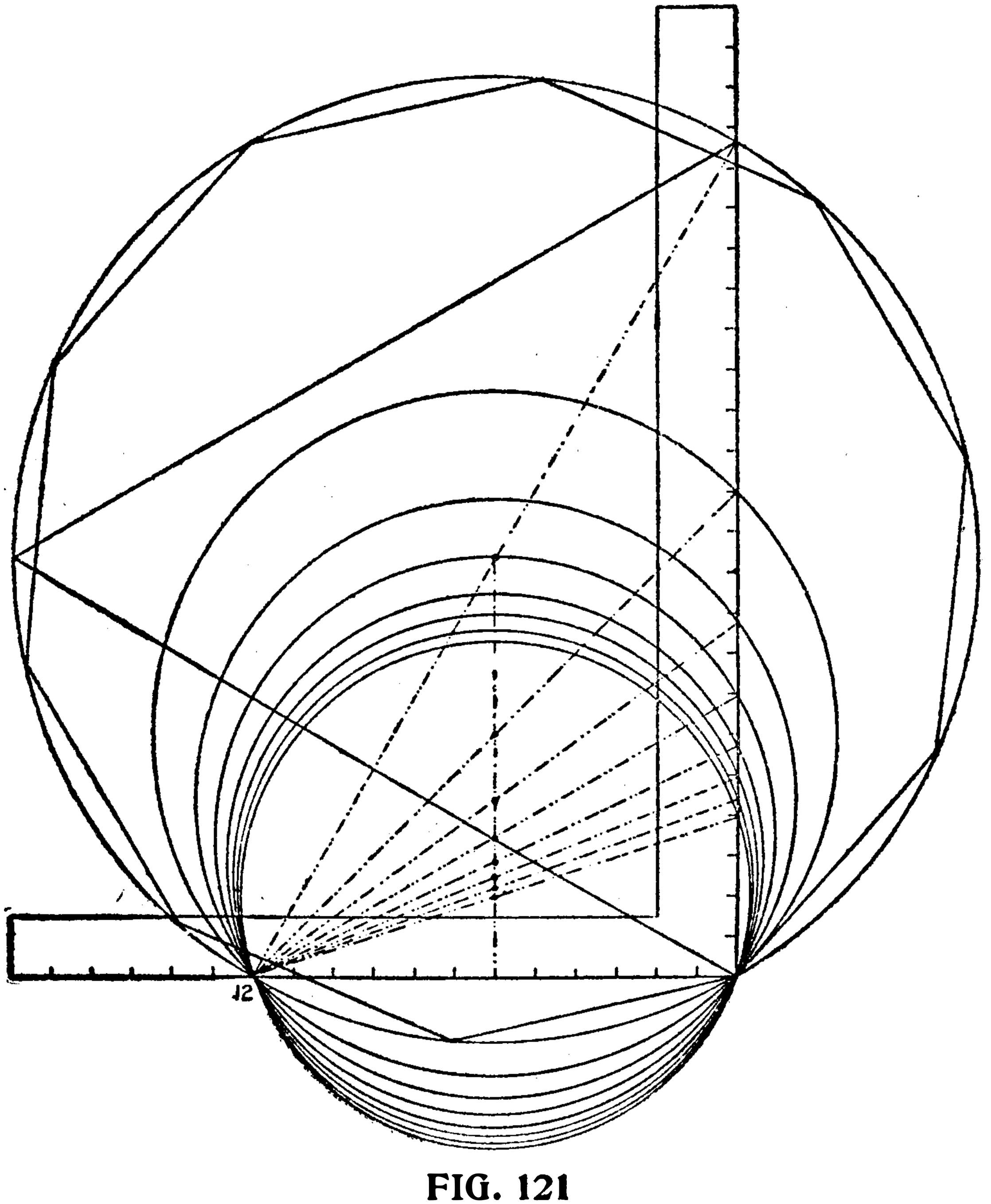

FIG. 121

yet according to trigonometry they could go on and on multiplying in number of sides and the decimal would never be entirely disposed of,

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leaving it in the infinitesimal or where the polygon really ends and the true circle begins.

In Fig. 122 is shown another way of handling the steel square in laying out the polygons. Here we show two squares as though they were pivoted at 12 on the tongue and made to work like a pair of shears. Just above this is shown the semi-circle with its 180-degree divisions also centering at 12. The degrees are read from the top each way and are to the steel square as the dial to the weighing scales. Thus, to find the side of an octagon, divide 180 by 8, equals 22½. Now swing the blades up until the tongues are in lines with 22½ degrees and the angle formed by the blades will be that of the octagon corner as shown in the illustration, 12 and the figures at the intersection of the blades (4 23-24) will give the required miter. The blade giving the cut. By laying off the desired circumscribed radius on a line directly below the intersection of the blades and where the circle intersects the line of the blade as from 4 23-24 to A will be the length of the desired sides. The quotient for the square, or tetragon, is 45, and that for the triangle is 60 degrees, as shown. For effect in the illustration, we have used one common center for the above polygons. The dotted lines represent the space over which the steel square would travel in laying out these polygons. By using the same center, the pentagon, hexagon and heptagon would come in their order between the tetragon or square and octagon,

and continue on as the number of sides is increased in the polygon.

We have one more illustration along this line we wish to present, as shown in Fig. 123. In this

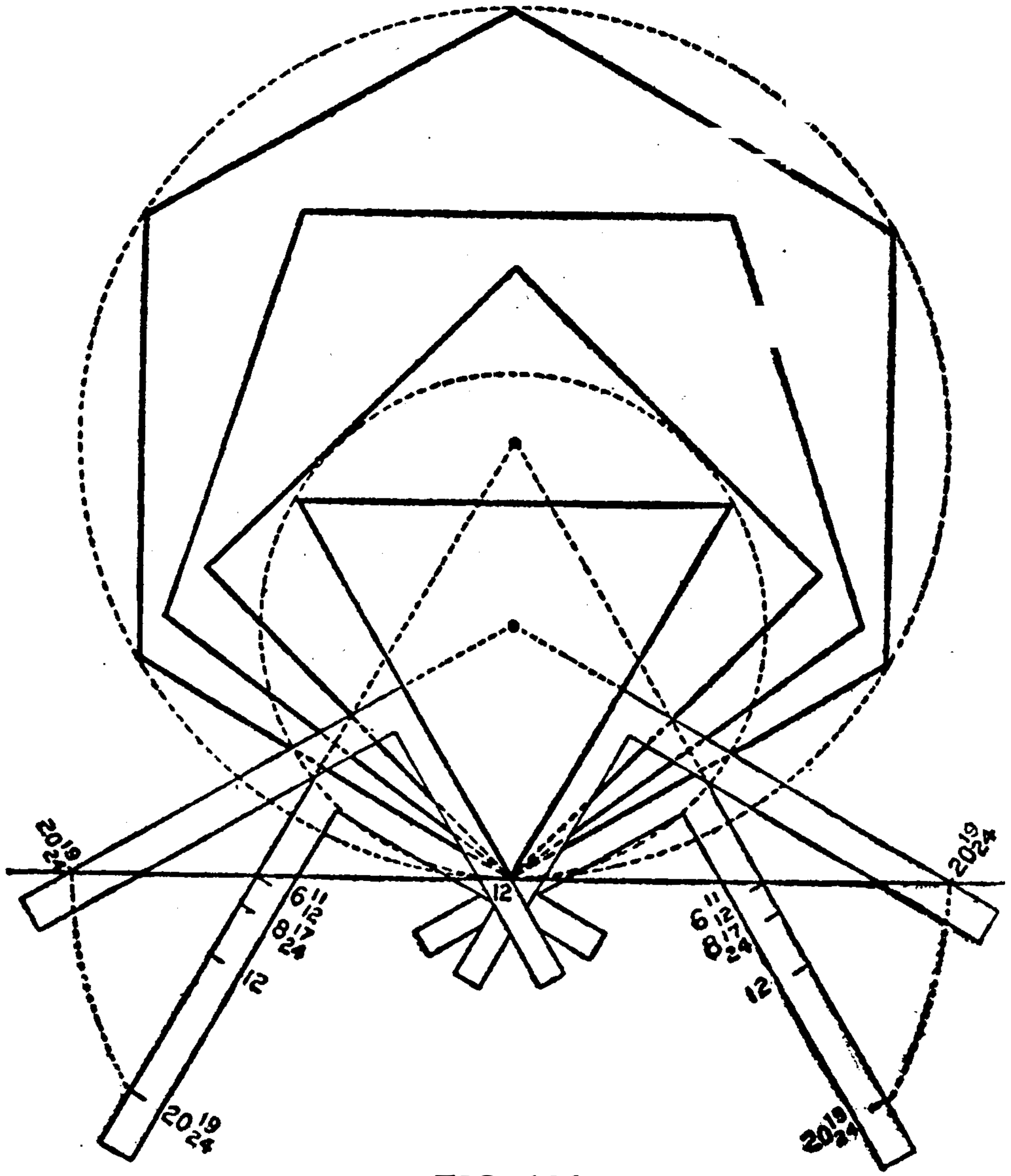

FIG. 123

we show four of the polygons beginning with the triangle and developed with the aid of the steel square from a straight line. The application of

the squares is shown for the triangle and hexagon with the figures given for the square and pentagon. Now just suppose the tongues of the steel square are pivoted at 12 to the line as shown. Now by raising the blade up until the figures on the one that give the miter, intersects the straight line, the angle formed by the tongues will be that of the corresponding polygon. According to the illustration the sides of all of the polygons are 24 inches in length, though they could be by this method laid out to any desired length and by squaring out from the sides at one-half of the desired length and the intersection of these lines will be the center of the desired polygon.

Laying Out a Circular Frame.—In Fig. 124, is shown how any part of a circular frame may be laid out with the aid of the steel square. If we wish to lay out one-sixth of the frame, it may be done as follows:

Lay off the desired radius as from A to B then apply the square with the 12-inch mark at A as shown and draw a line from 12 on the tongue, passing at 6 11-12 inches on the blade and drop to an equal amount on a plumb line below the heel, then that part of the frame as from C to D will represent one of the desired pieces, and by applying the square to the chord line, as shown, will give the required miter. Proceed in like manner for four pieces, using 12 on the blade and the space from E to F will be one of the desired pieces. The space from C to B represents one-twelfth and from E to B, one-eighth of the complete

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degrees from either side, and 76 degrees from 90 degrees leaves 14 degrees. We find the tangent for 14 degrees to be 2.99 or practically, 3 inches. Therefore, 12 on the tongue and 3 inches on the blade will give the miter, the latter giving the

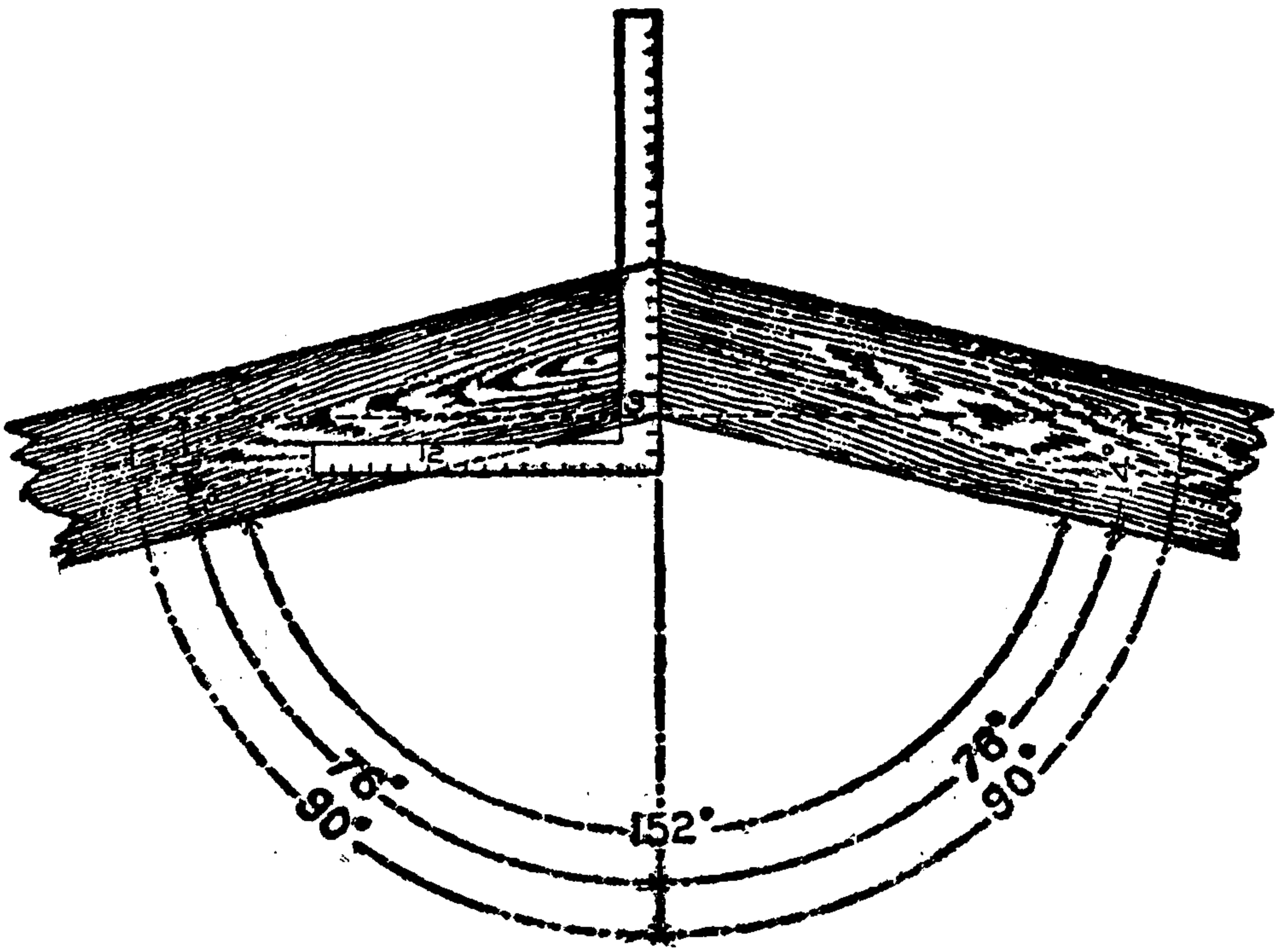

FIG. 125

cut. The square as placed would give the cuts for a brace set to either 14 or 76 degrees.

Ornamental Figures in Miter Work.—We will now call the attention of the reader to a few ornamental figures in miter work that may be accomplished by the aid of the compass and steel square. In this there is a wide field for culture with practically no end. We have prepared for this work a few designs along this line and the mechanically inclined will find in these excellent

practice and if he has an eye for designing, these also will furnish a nucleus upon which to plan other designs that will not only give practice and perfection in handling the steel square, but will help to broaden his knowledge in its use and place him on a higher plane in his chosen profession.

The equilateral triangle is more susceptible of changes in ornamental design than any of the other polygons for the reason that the length of its sides are the radius of the circumscribed diameter of the hexagon. Its area being one-sixth that of the latter, and the same figures used on the steel square for the miter of one also gives it for the other as we have previously shown.

Arrangement of the Triangle.—The triangle can be arranged in many designs or patterns and leave no intervening spaces, as will be seen by

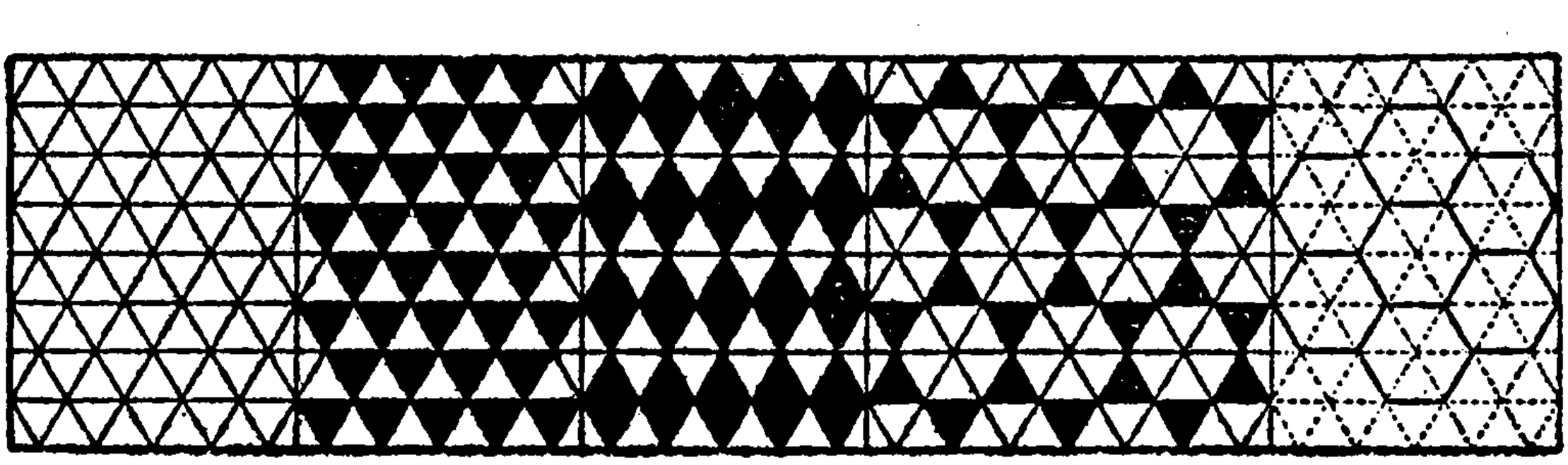

FIG. 126

referring to Fig. 126, which adapts itself to ornamental tile or inlaid work. Even the little honey bee understands the geometric principles in space saving and constructs her store house accordingly in hexagonal cells, which are in the form of six

equilateral triangles and so arranged that they interlock each other as shown in part of the illustration. The equilateral triangle may indeed be classed as the monarch of all the polygons, for within its lines as a basis, any of the other polygons may be drawn to any desired size, as we will show later on under another head.

In Fig. 127, is shown a hexagonal figure in general design and all of the miters can be had on

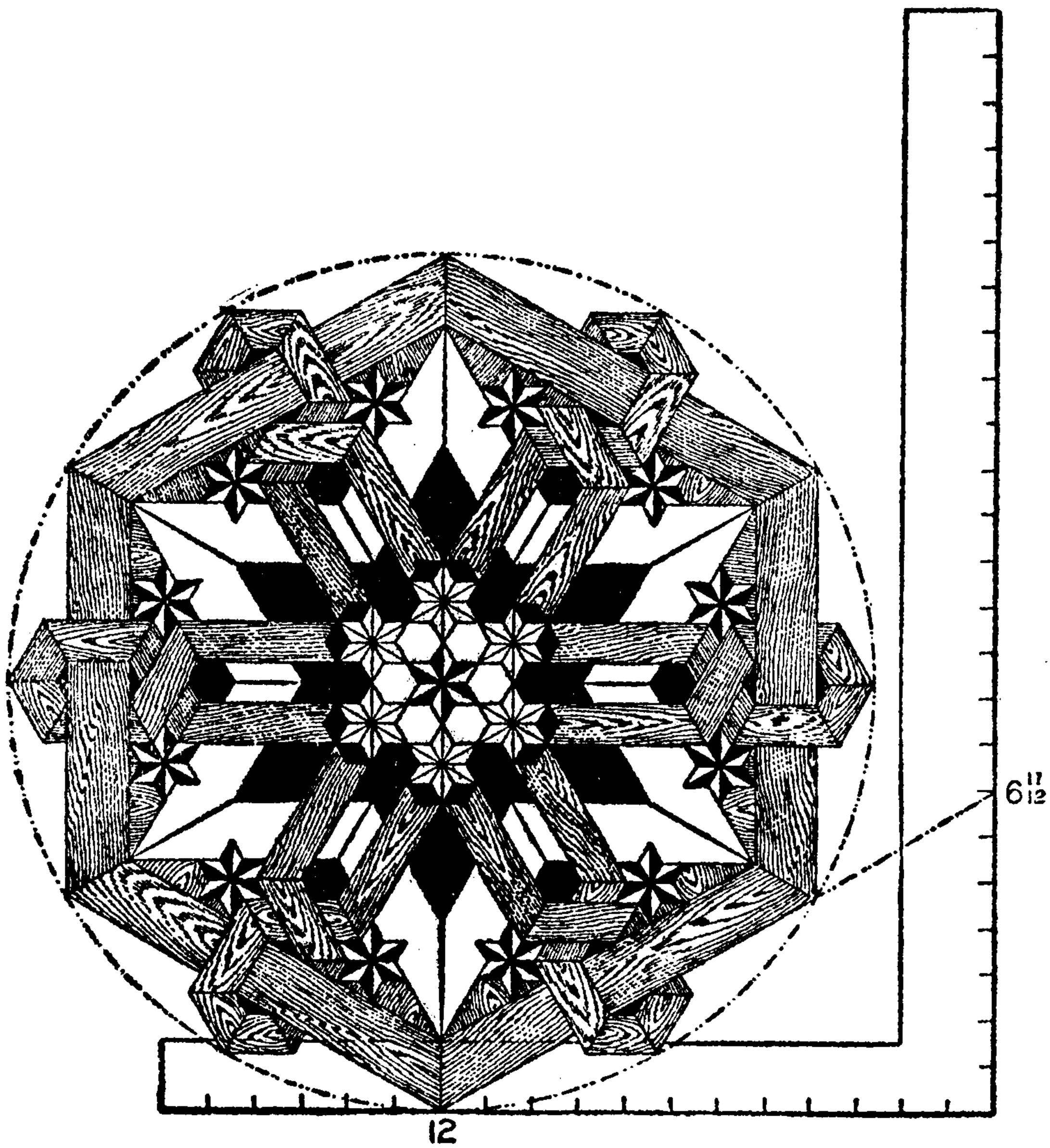

FIG. 127

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shaped frames inclosed in circles and these are contained in one large hexagon and the whole in one large circle.

The reader will notice that the figures given on the square are the same as those given in previous illustrations for the miter of the hexagon.

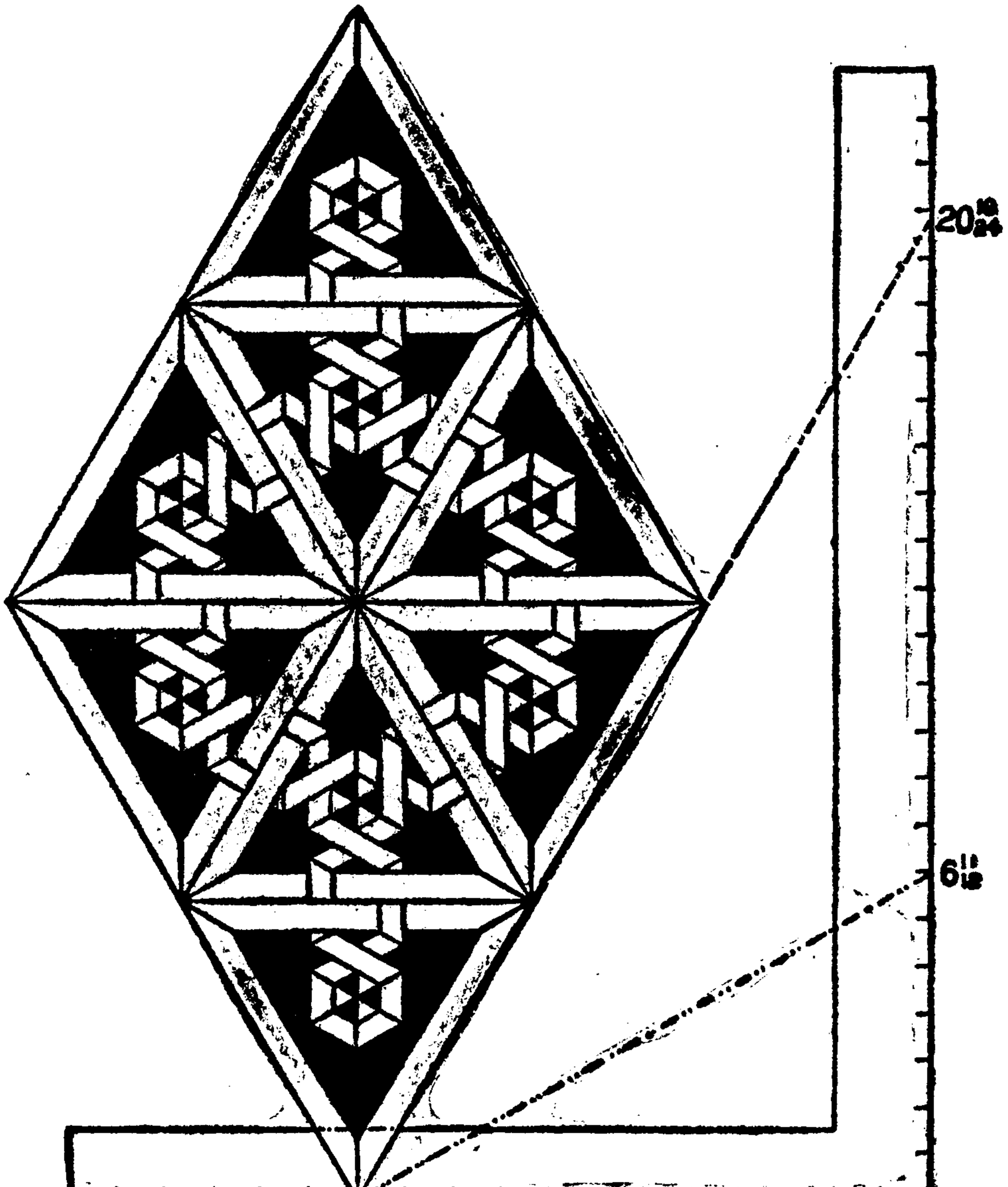

FIG. 128

The blade will give the angle for the inner points, while the tongue will give it for the outer points, or if 60 degrees is used, which falls at 20 19-24 on the blade, then the angles will be just the reverse on the square.

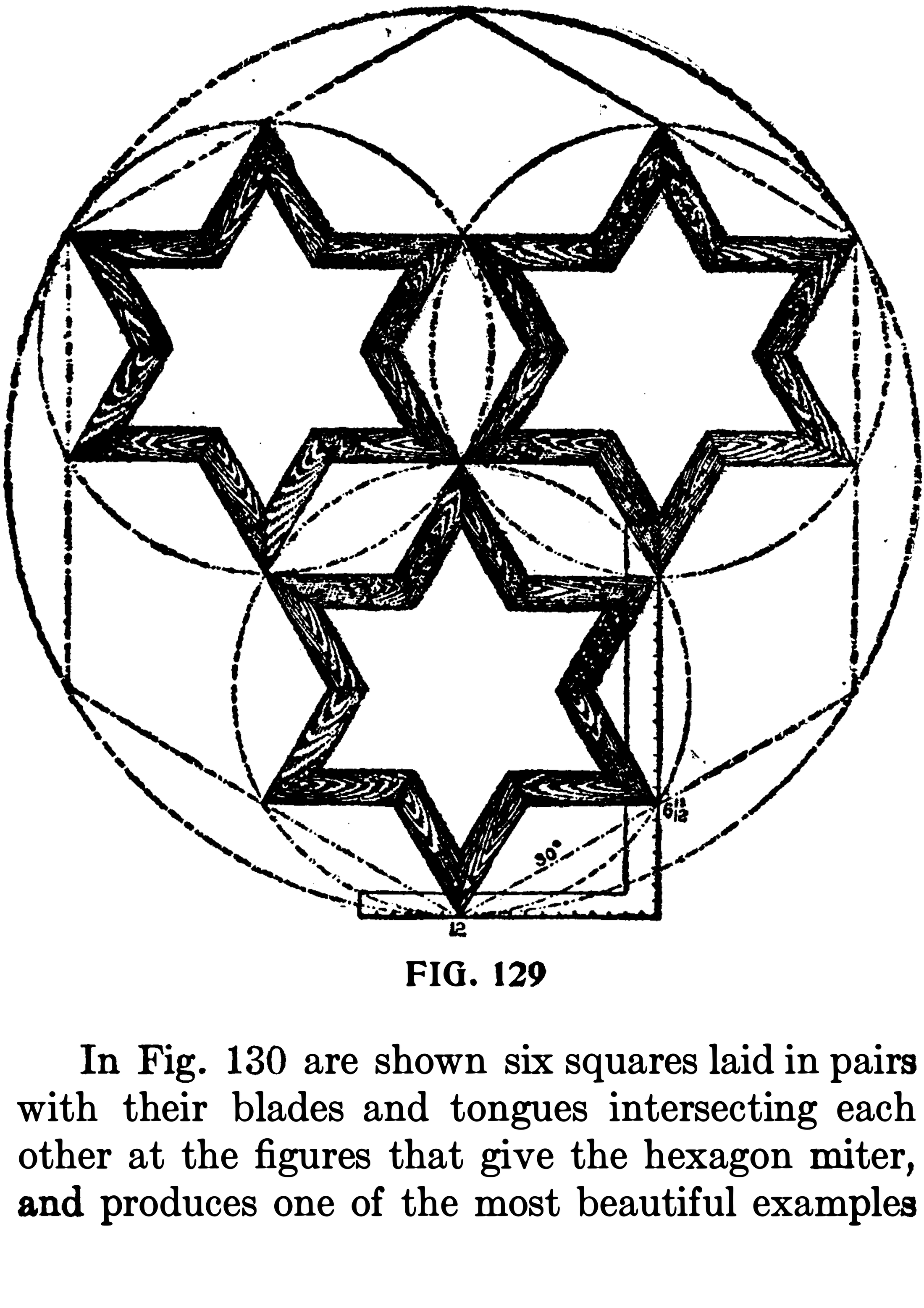

FIG. 129

In Fig. 130 are shown six squares laid in pairs with their blades and tongues intersecting each other at the figures that give the hexagon miter, and produces one of the most beautiful examples

in miter work. All of the angles about the squares form some part of the hexagon and it will be seen that the large circle that incloses the figure is equally divided into six parts.

In Fig. 131 is shown another form of drawing polygonal figures. In this we show two squares,

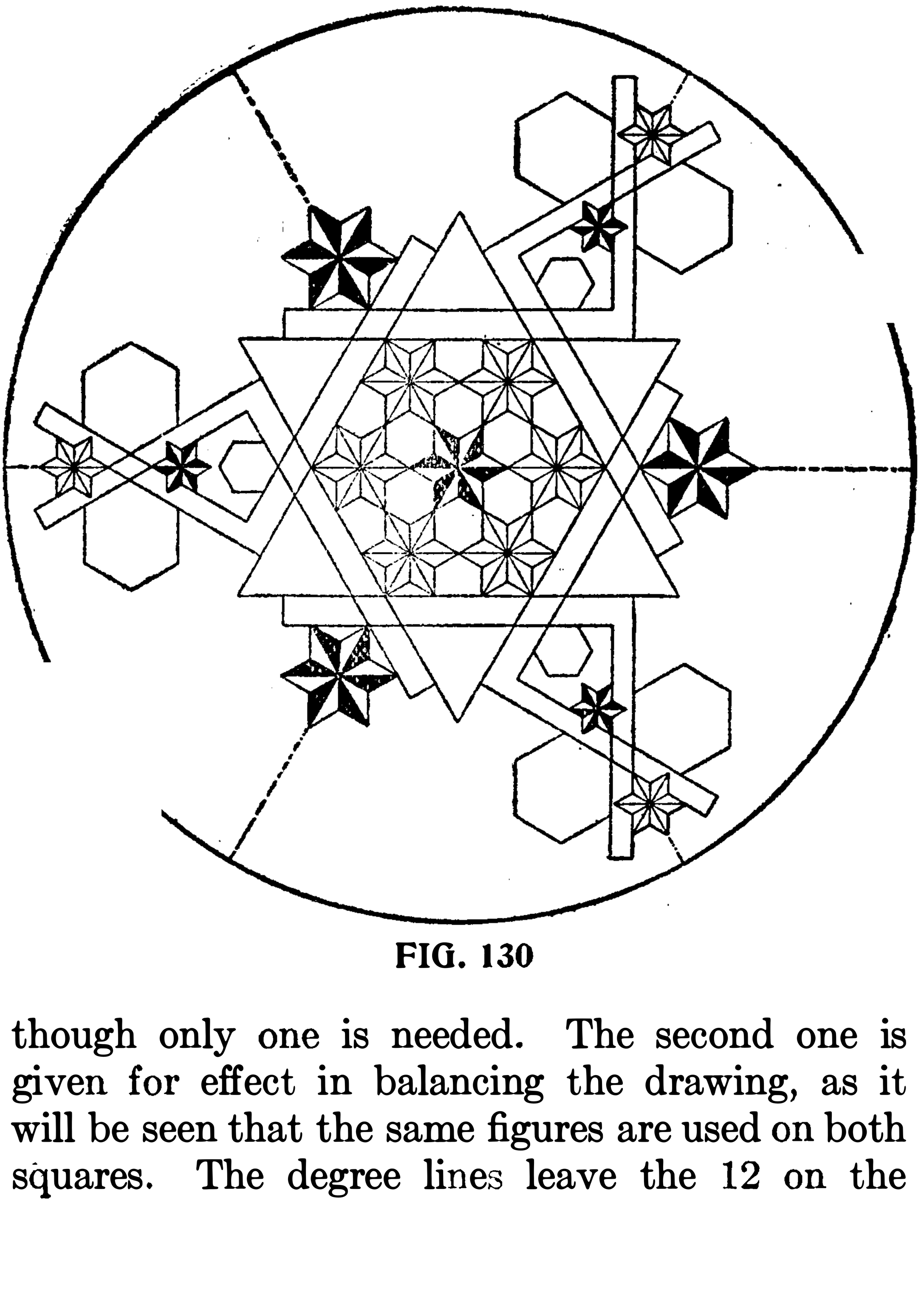

FIG. 130

though only one is needed. The second one is given for effect in balancing the drawing, as it will be seen that the same figures are used on both squares. The degree lines leave the 12 on the

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polygons of the above number of sides are all contained in this figure.

In Fig. 132 we have carried the above a little further, showing the same polygons as in the pre-

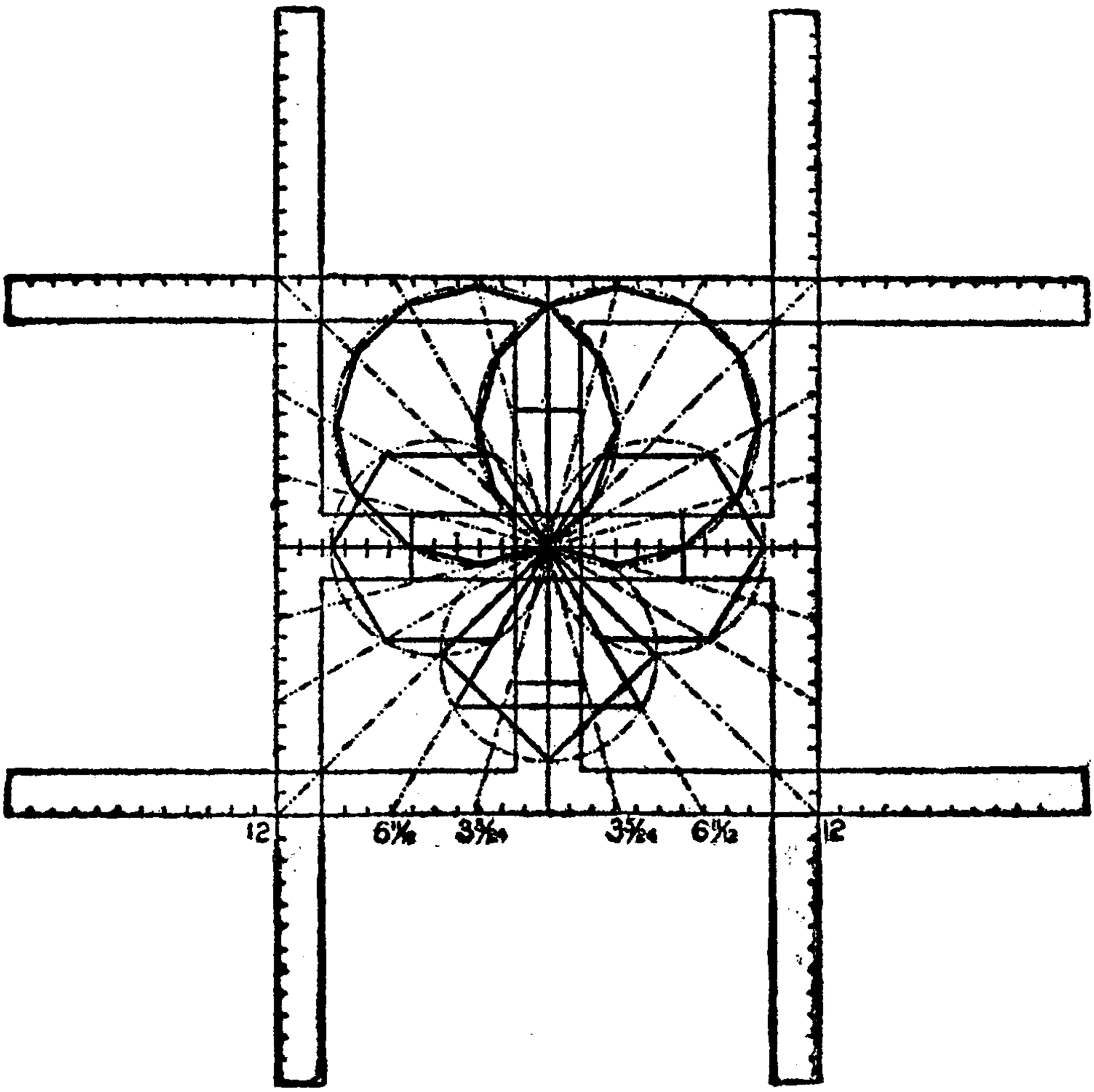

FIG. 132

ceding figure, but in this case they have blossomed out into a flower.

In Fig. 133 is shown a diagram whereby the angles and dimensions for any of the polygons may be accurately drawn by a system of lines passing through 12 on the tongue of the square.

For illustration we have taken the heptagon or seven-sided figure.

The semi-circle 7-A is first drawn, which may be to any desired size. Place the steel square as shown with the 12-inch mark at the center.

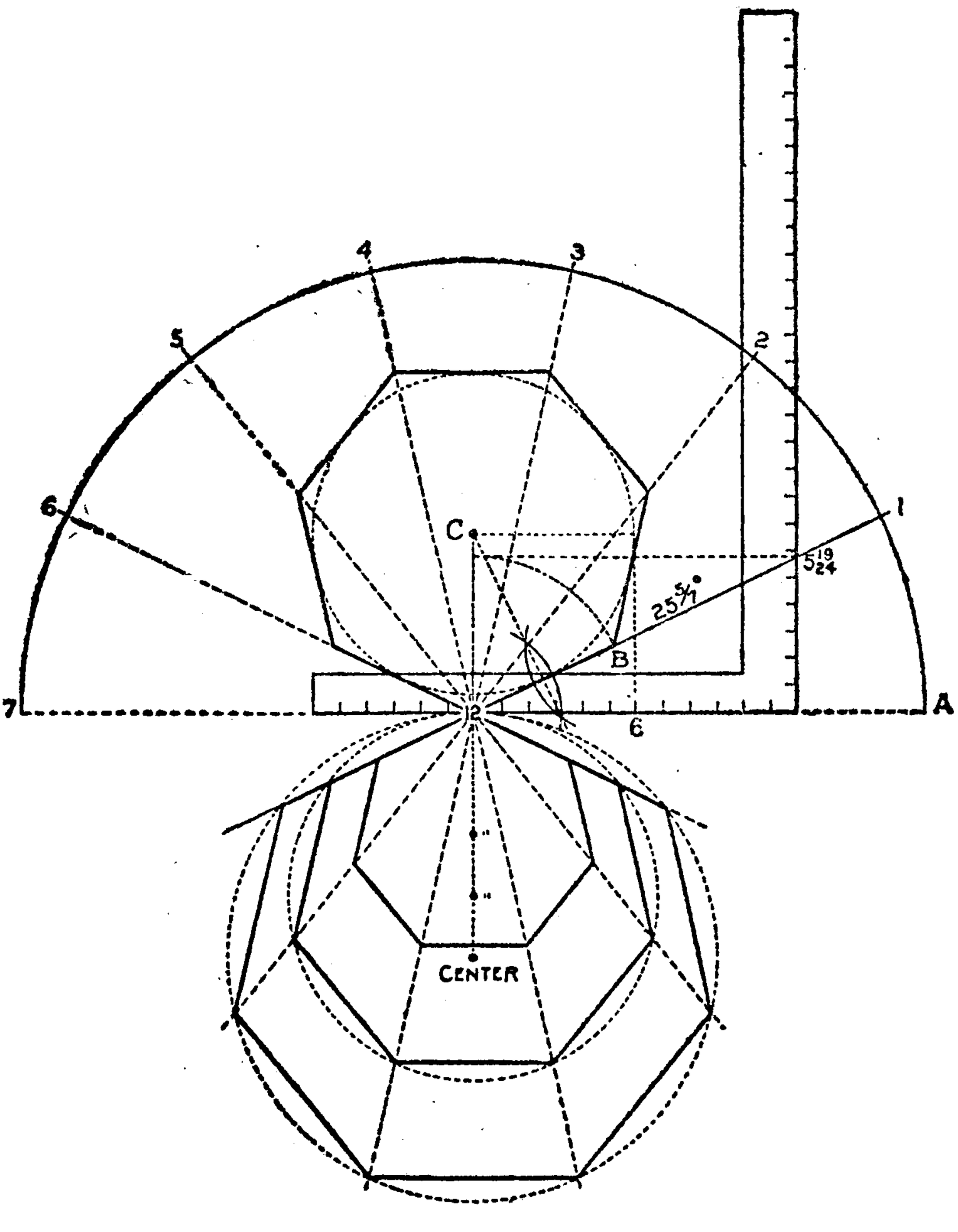

FIG. 133

Then draw a line from 12, passing at 5 19-24 on the blade (which are the figures to use for the miter), and continue on, intersecting the semi-circle at 1. Then A-1 will represent one-seventh of the semi-circle and is equal to the spacing set off at 1, 2, 3, etc. Draw lines from these points to the center at 12, as shown.

Drawing a Heptagon.—Now, suppose we wish to draw a heptagon with a twelve-inch inscribed diameter. Set off 5 19-24 on the line 12-1, as at B, and bisect the line 12-B as shown, and where the bisecting line intersects the perpendicular line from 12, as at C, will be the center from which to strike the required radius.

By indefinitely extending the lines 1, 2, 3, etc., below 12, as shown, heptagons with any desired circumscribed radius may be readily determined by simply setting off the radius on the perpendicular line as shown, and where the circle cuts the extended lines determines the length of their chords or sides. In the illustration we have shown three sizes. Proceed in like manner for any of the other polygons, but using the figures on the blade of the square that give their miters.

In Fig. 134 we show two squares with the blades and tongue intersecting at the figures that give the pentagon miter, and as will be seen, all of the angles form part of the pentagon. The stars are shown in connection with the same to further illustrate the accuracy of the illustration.

In Fig. 135 the lines are at 18 degrees on the square at the lower point of the star, and as will

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their tongues in line with the 18 degree lines from the two lower squares, and form the angles for other parts of the star.

It will be seen that a star-shaped figure can be systematically framed either in the solid or in

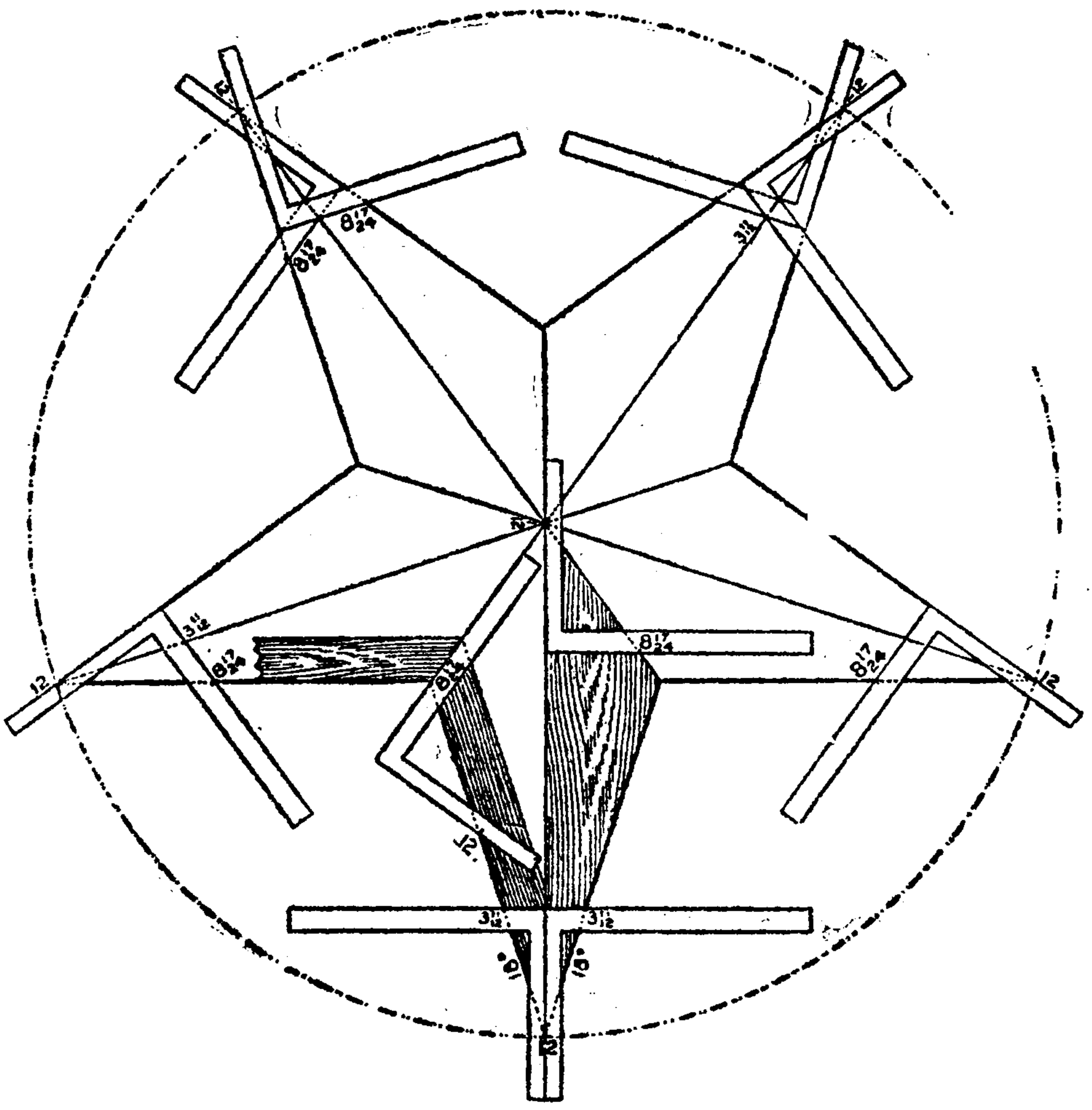

FIG. 135

part, as shown, and that without first laying out a full-sized diagram, and the ten pieces will fit to their respective places. The figures 12 and 8 17-24 also furnish the basis for framing a root of

this shape, and the general rule that applies to this, applies to all angles.

Tangents and Co-Tangents.—In Fig. 136 we have tried to make the subject of tangents and co-tangents clear by the use of two steel squares,

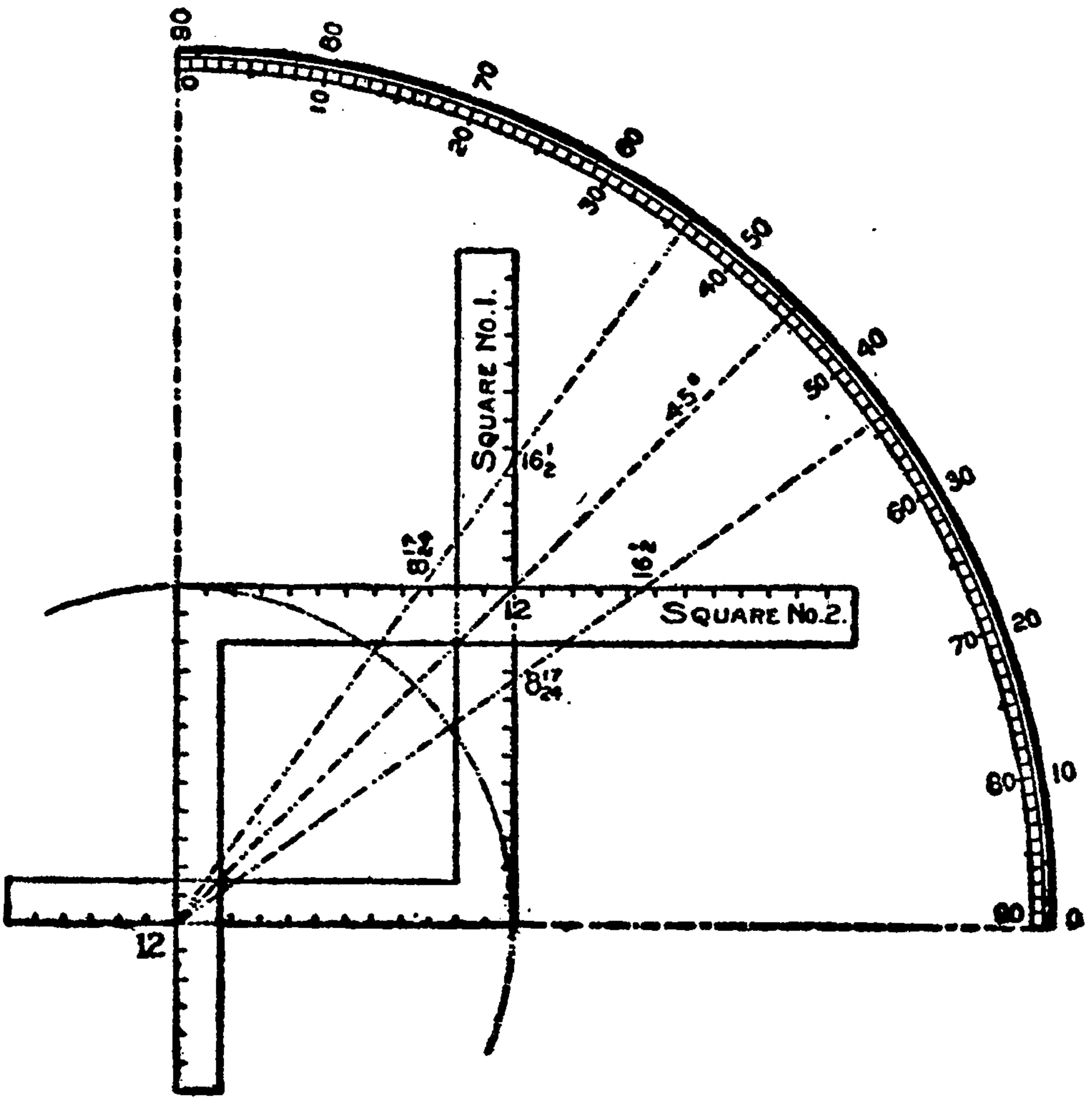

FIG. 136

placed as shown in connection with the quadrant. The blades and tongues intersecting at 12 and 12. Now, since a tangent is simply a straight line touching the side of a circle, we let the blades represent the straight lines intersecting a circle

described from 12 on the tongue. Reading from the bottom up, the 36-degree line passes at 8.72 (8 17-24 inches) on the blade of square No. 1, and from this back to the heel is the tangent. Now, referring to square No. 2, what was 36 degrees

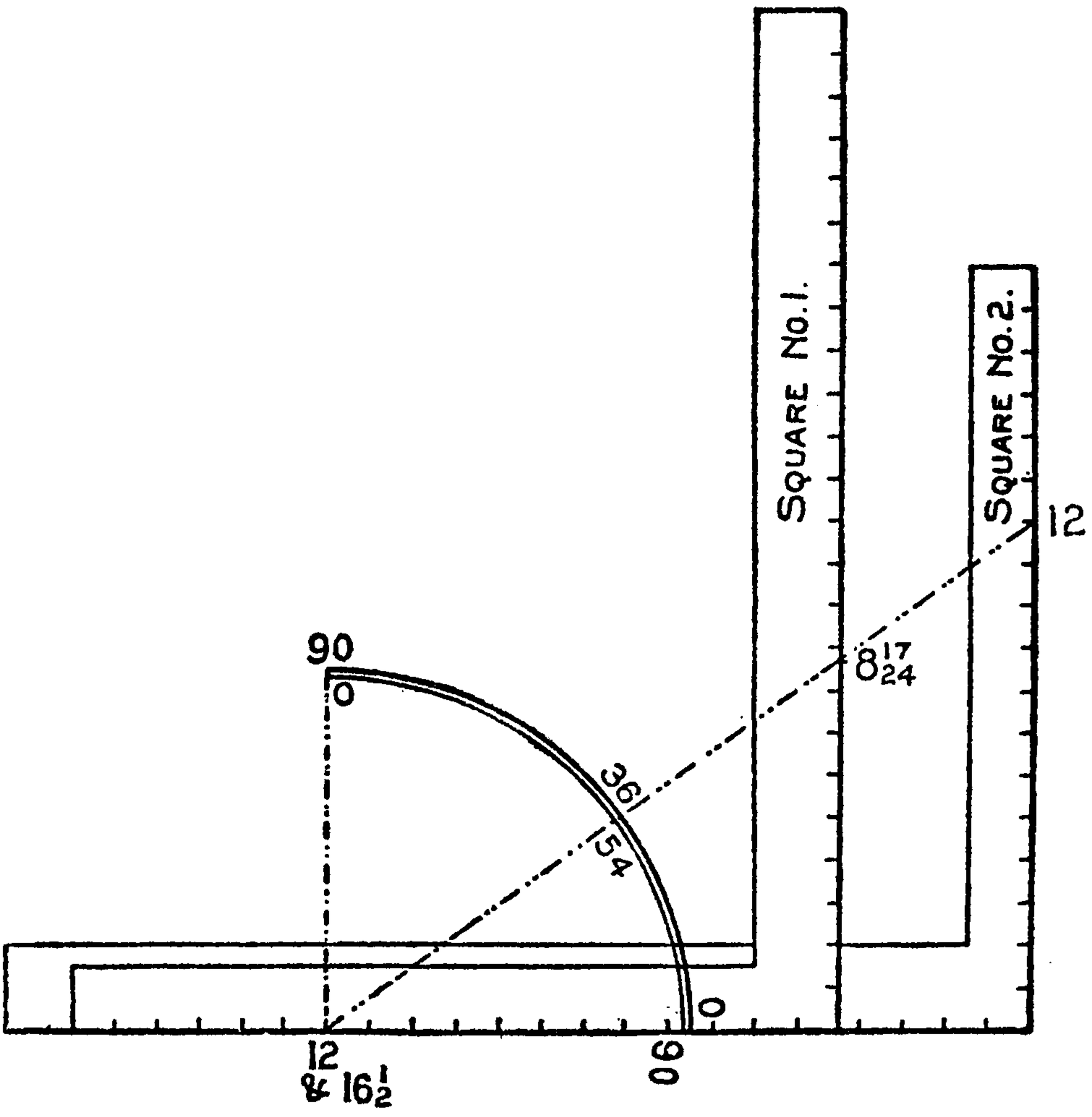

FIG. 137

on square No. 1 is 54 degrees, and passes at 16.51 (16½ inches), and from this point back to the heel is the co-tangent. Both squares give identically the same cut, in other words, what the

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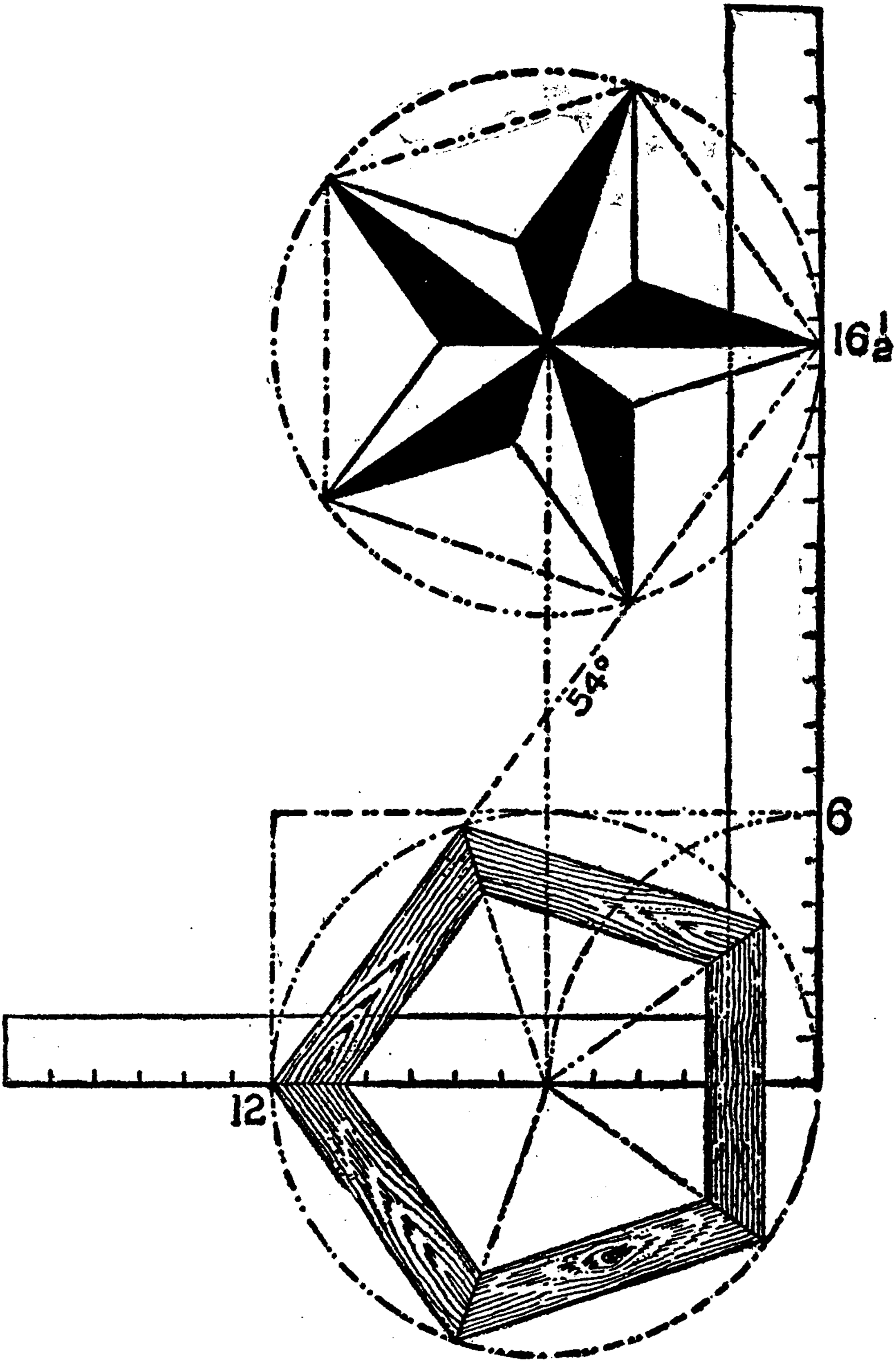

FIG. 139

using the same figures on the squares as in Fig. 136 for the 36 and 54-degree line. Taking the squares separately, we show in Fig. 138, using the 36-degree line, the pentagon miter on the blade and the pentagon star resting at 12 on the tongue; while in Fig. 139, using the 54-degree line, the

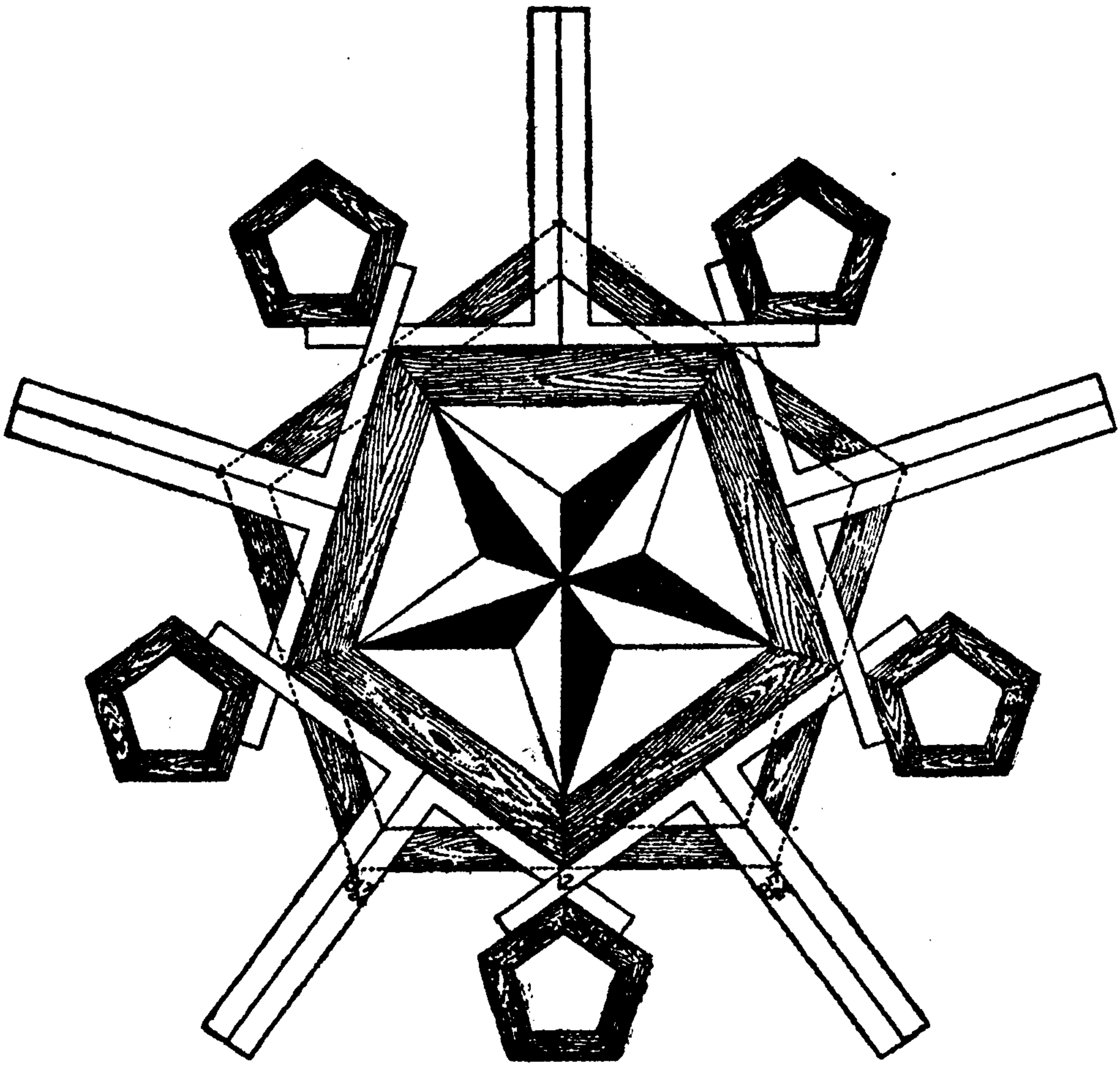

FIG. 140

reverse is shown. In both of these illustrations the pentagon frame and star are inclosed in a circumscribed diameter of 12 inches, but they could be of any desired size.

We have one more pentagonal illustration as

shown in Fig. 140, we wish to present before passing on to some of the other polygons. We could go on and show other positions of the steel square in forming the pentagon and its miters, but the figures used on the steel square would conform to the figures here given or to their ratio. We will now call the reader's attention to some of the other polygonal figures, applying the same rule as for the pentagon or five-sided figure.

Degree Line of Triangle and Hexagon.—The triangle and hexagon are the only polygons whose

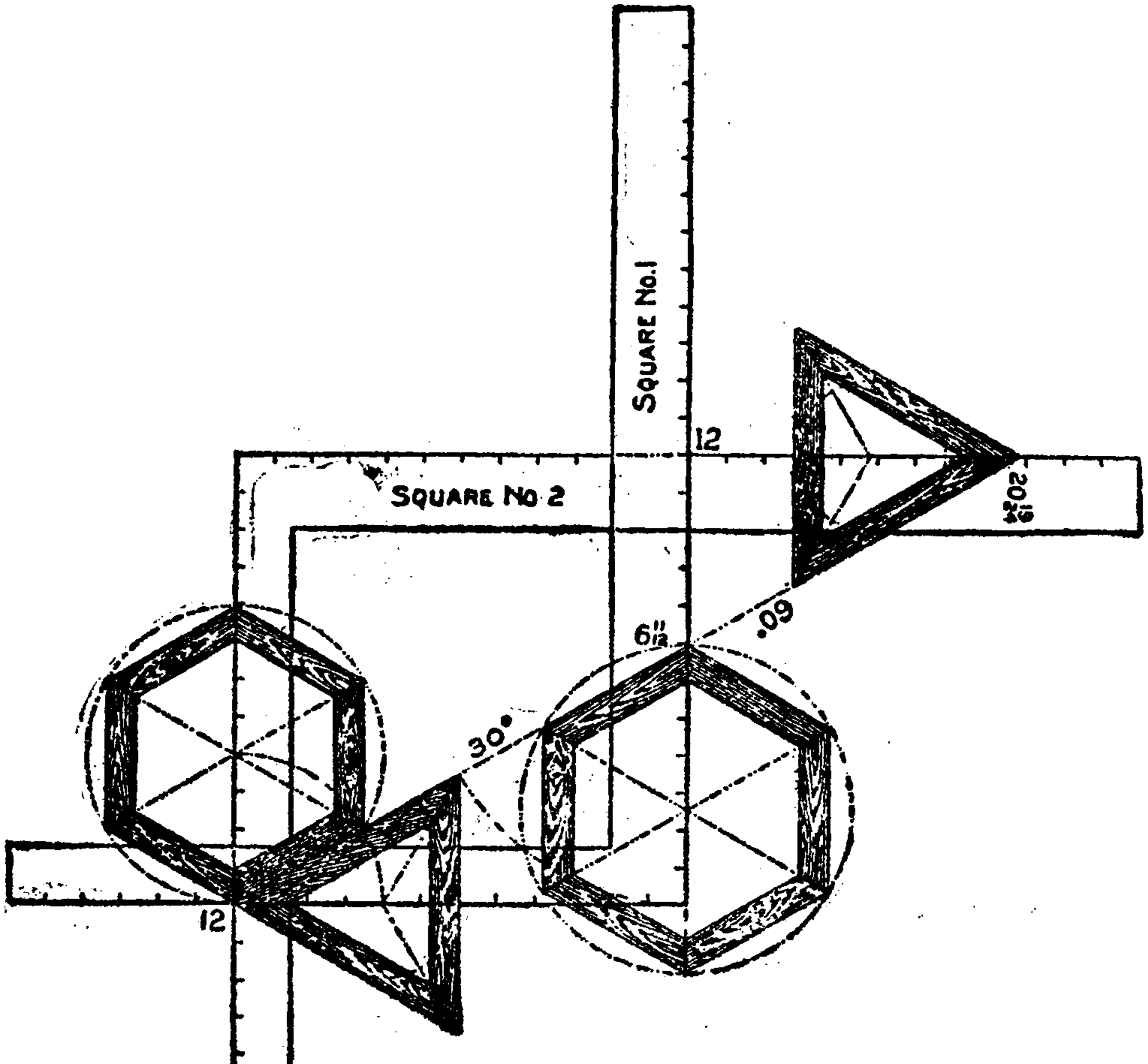

FIG. 141

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No. 2 and both giving the same cuts but reversed on the squares. Perhaps this point could be made more clear by using but one square as shown in Fig. 142. In this, the degree lines are shown for the 30 and 60 degrees and both giving the miter for the triangle. The tongue giving it in the former and the blade in the latter. In this example, we show how to lay off a triangle of any inscribed diameter by setting off the radius, say 2½ inches on the blade as shown, and squaring out to the degree line as at "A." Then with the length from 12 to "A," set off on the tongue will locate the center as at "B," or vice versa if the cut is wanted on the blade.

In Fig. 143, we show a circle with the degree divisions spaced on same with the aid of the steel square. We do not claim this to be the best way, nor would we use this method if we had a job of this kind to do, but it can be done and that very accurately, by letting 12 on the tongue rest at the center and checking on the blade as follows: 2⅛, 4⅜, 6 11-12, 10 1-12, 14 7-24 and 20 19-24 inches, which places the degree lines ten degrees apart. Then swing the square till the tongue rests in line over the last check and repeat the markings. Six movements of the square will complete the divisions and with a straight edge, which may be the blade of the square passing from the center and over the check marks, will divide the circle in divisions of ten degrees, and these may be divided with a compass into ten spaces, designating the degrees. Of course, the whole circle could have

been divided with the compass by first dividing the circle into quarters or sixths and these spaces again into the required divisions, but the reader will understand that we are illustrating what may be done with the aid of the steel square. How-

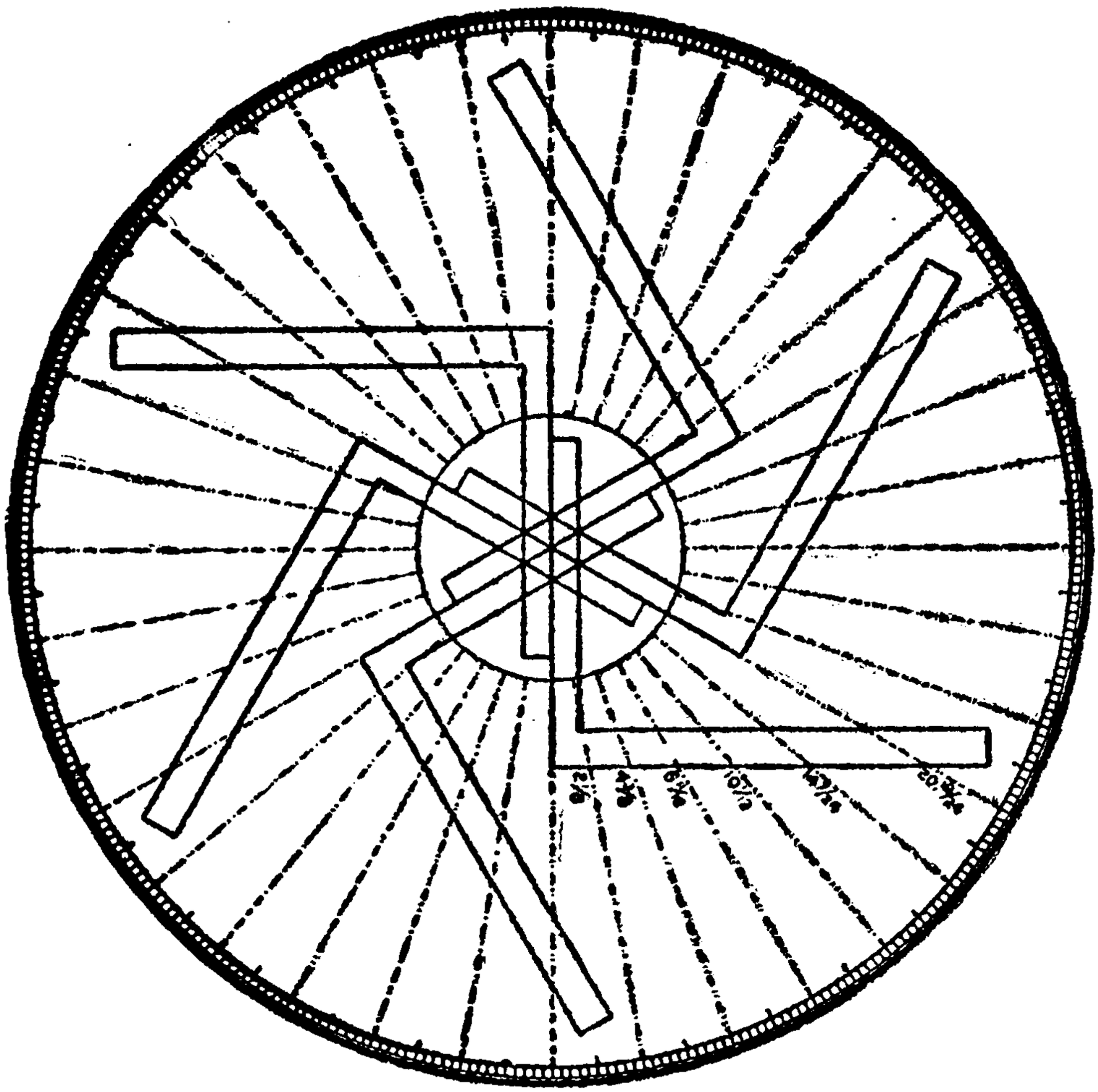

FIG. 143

ever, it will not be out of place to show what may be done with the compasses alone in laying off the degrees on the circle as shown in Fig. 144, and may be drawn as follows:

Laying Off Degrees With Compasses.—With the compass describe the degree circle and without changing the radius, set the needle point at any place on the circle, describe another circle and at the intersection with the first circle, describe

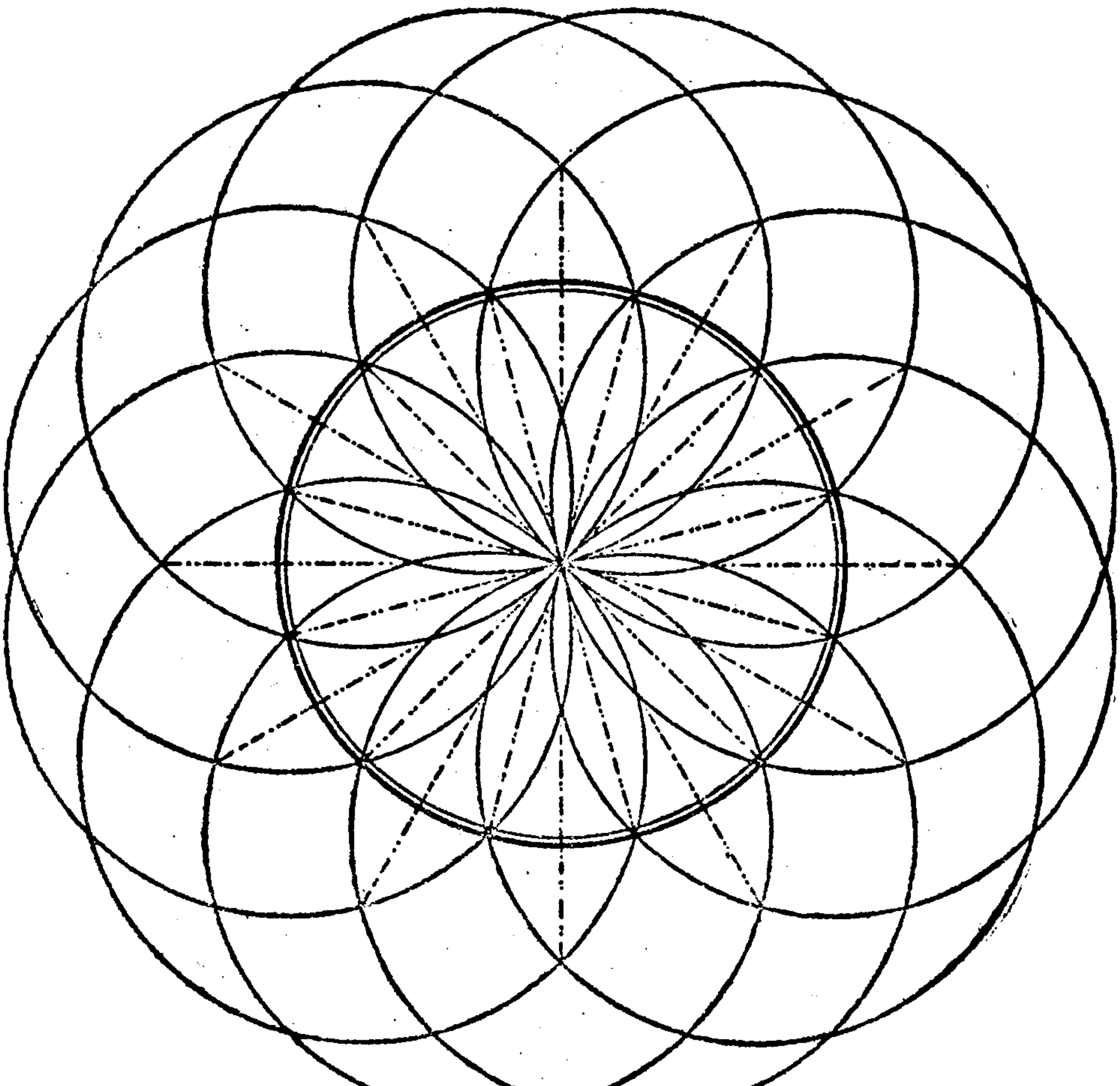

FIG. 144

another circle and continue until all of the intersections have been used; then with a straight edge lay off the lines through the center to the intersection of the points of the outer circles. It will be seen that the degree circle has been

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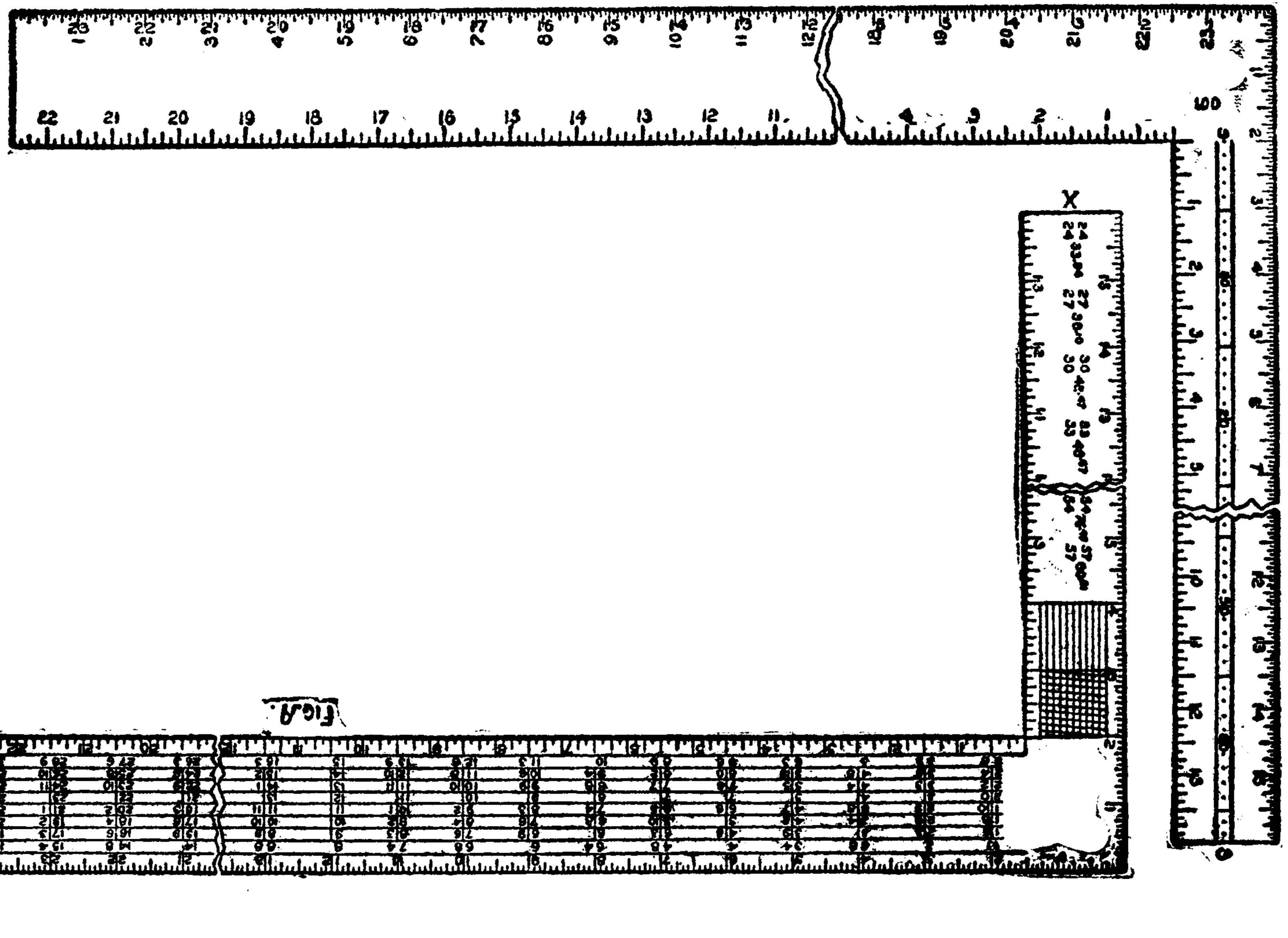

Miscellaneous Rules

In connection with the work of construction, problems frequently arise that are ordinarily supposed to involve the necessity for more or less complicated mathematical computation in their solution. In the case of many of these problems, it will be found that a familiar knowledge of the possibilities of the steel square and an intelligent use of this instrument will afford a simple and at all times available solution. Such problems are, for example, to measure a pile of lumber, to estimate the number of square yards in a job of plastering or painting, etc.

The following rules and examples have been gathered from various sources, and although they touch upon topics already treated, they are here presented with the confident belief that the reader will find among them a number of easy solutions of problems of more or less complexity that heretofore have caused him much time and trouble to work out.

Measurement.—Let us suppose that we have a pile of lumber to measure, the boards being of different widths, and say 16 feet long. We take our square and a bevel with a long blade and proceed as follows: First we set the bevel at 12 inches on the tongue of the square, because we want to find the contents of the board in feet,

12 inches being one foot; now we set the other end of the bevel blade on the 16 inch mark on the blade of the square, because the boards are 16 feet long. Now, it must be quite evident to any one who would think for a moment, that a board 1 foot wide, and 16 feet long, must contain 16 feet of lumber. Now let us take a board 11 inches wide, and 16 feet long, we just move our bevel from the 12 inch mark to the 11 inch mark, on the tongue, and look on the blade of the square for the true answer; and so on with any width, so long as the length is 16 feet. If the stuff is two inches thick, double the answer, if three inches thick treble the answer, etc.

Now, if we have stuff 14 feet long, we simply change the bevel blade from 16 inches on the square blade, to 14 inches, keeping the other end of the bevel on the 12 inch mark, 12 inches being the constant figure on that side of the square.

To Find Number of Yards of Plastering or Painting.—If we want to find out how many yards of plastering or painting there are in a wall, it can be done by this method quite easily. Let us suppose a wall to be 12 feet high and 18 feet long, and we want to find out how many yards of plastering or painting there are in it, we set the bevel on the 9 inch mark on the tongue (we take 9 inches because 9 square feet make one square yard, (we take 18 inches, one of the dimensions of the wall, on the blade of the square; then after screwing the bevel tight, we slide it from 9 inches to 12 inches, the latter number

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18, for dividing the board into four equal parts; or at 4, 8, 12, 16, and 20, if it is desired to divide the board into six equal parts. Of course the common two-foot rule will answer this purpose as well as the square, but it is not always convenient.

To Obtain Diagonal of Parallelogram. — If the diagonal of a parallelogram withint he range of the square is required, it can be obtained as follows: Set the blade of the bevel on $8\frac{3}{4}$ inches on the tongue of the square, and $12\frac{3}{8}$ inches on the blade; securely fasten the bevel at this

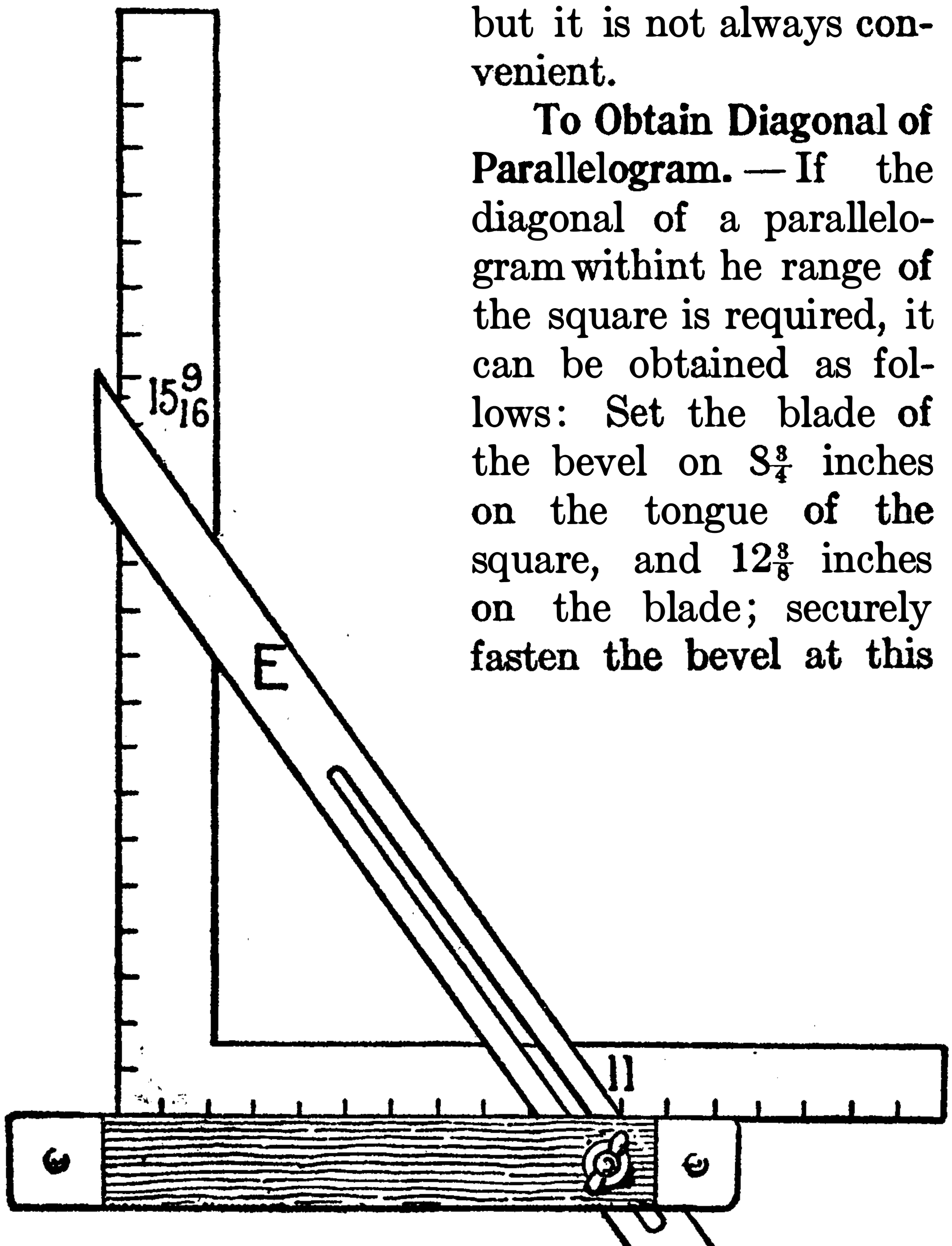

FIG. 146

angle. Now, suppose the parallelogram or square as in Fig. 146 to be 11 inches on the side, then move the bevel to the 11 inch mark on the tongue of the square, and the answer, 15 and 9-16, will be found on the blade. All problems of this nature can be solved with the square and bevel as the latter is now set. There is no particular reason for using $8\frac{3}{4}$ and $12\frac{3}{8}$, only that they are in exact proportion to 70 and 99. $4\frac{3}{8}$ and 6 3-16 would do just as well, as they are in the same proportion.

To Find the Circumference of a Circle with the square and bevel proceed as follows: Set the bevel to 7 on the tongue and 22 on the blade; move the bevel to the given diameter on the tongue of the square, and the approximate answer will be found on the blade. When the diameter is wanted the operation is simply reversed, that is, we put the bevel on the blade and look on the tongue of the square for the answer.

To Find Side of Greatest Square in a Circle.—If we want to find the side of the greatest square that can be inscribed in a given circle, when the diameter is given, we set the bevel to $8\frac{1}{2}$ on the tongue and 12 on the blade. Then set the bevel of the diameter on the blade, and the answer will be found on the tongue.

To Determine Proportions of Cylindrical Bodies.—In Fig. 147 is shown a method to determine the proportions of any circular presses or other cylindrical bodies, by use of the square. Suppose the small circle, N, to be five inches in diameter

and the circle R is ten inches in diameter, and it is required to make another circle, Z, to contain the same area as the two circles N and R. Measure line a, on the square, from five on the tongue to ten on the blade, and the length of this line A from the two points named will be the diameter of the larger circle Z. And again, if you want

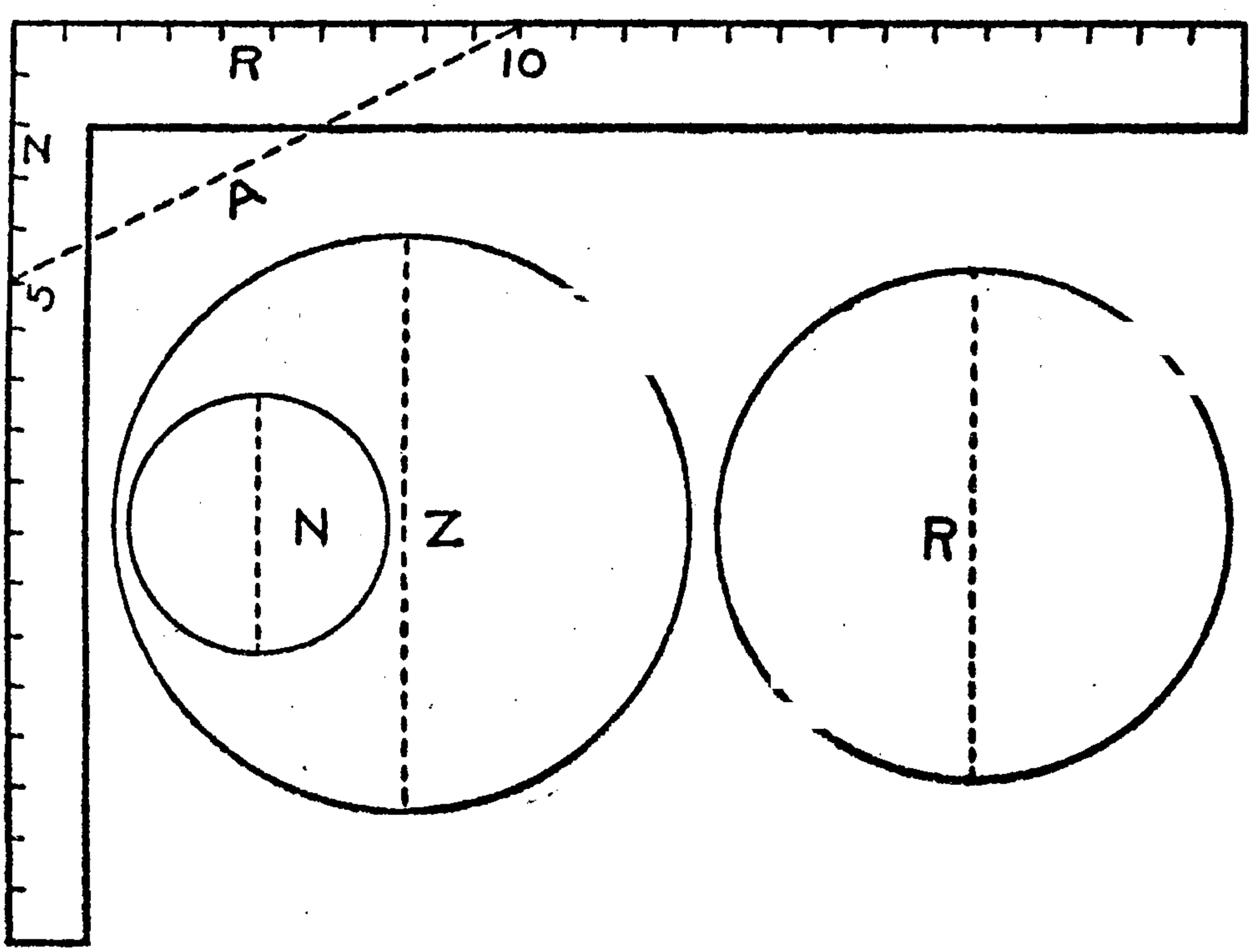

FIG. 147

to run these circles into a fourth one, set the diameter of the third on the tongue of the square, and the diameter of Z on the blade, and the diagonal will give the diameter of the fourth or largest circle, and the same rule may be carried out to infinite extent. The rule is reversed by taking the diameter of the greater circle and laying diagonally on the square, and letting the ends touch

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on the principle that a circle can be drawn through any three points that are not actually in a straight line. Suppose we take A B C D for four given points, then draw a line from A to D, and from B to C; get the center of these lines, and square from these circles as shown, and where the square

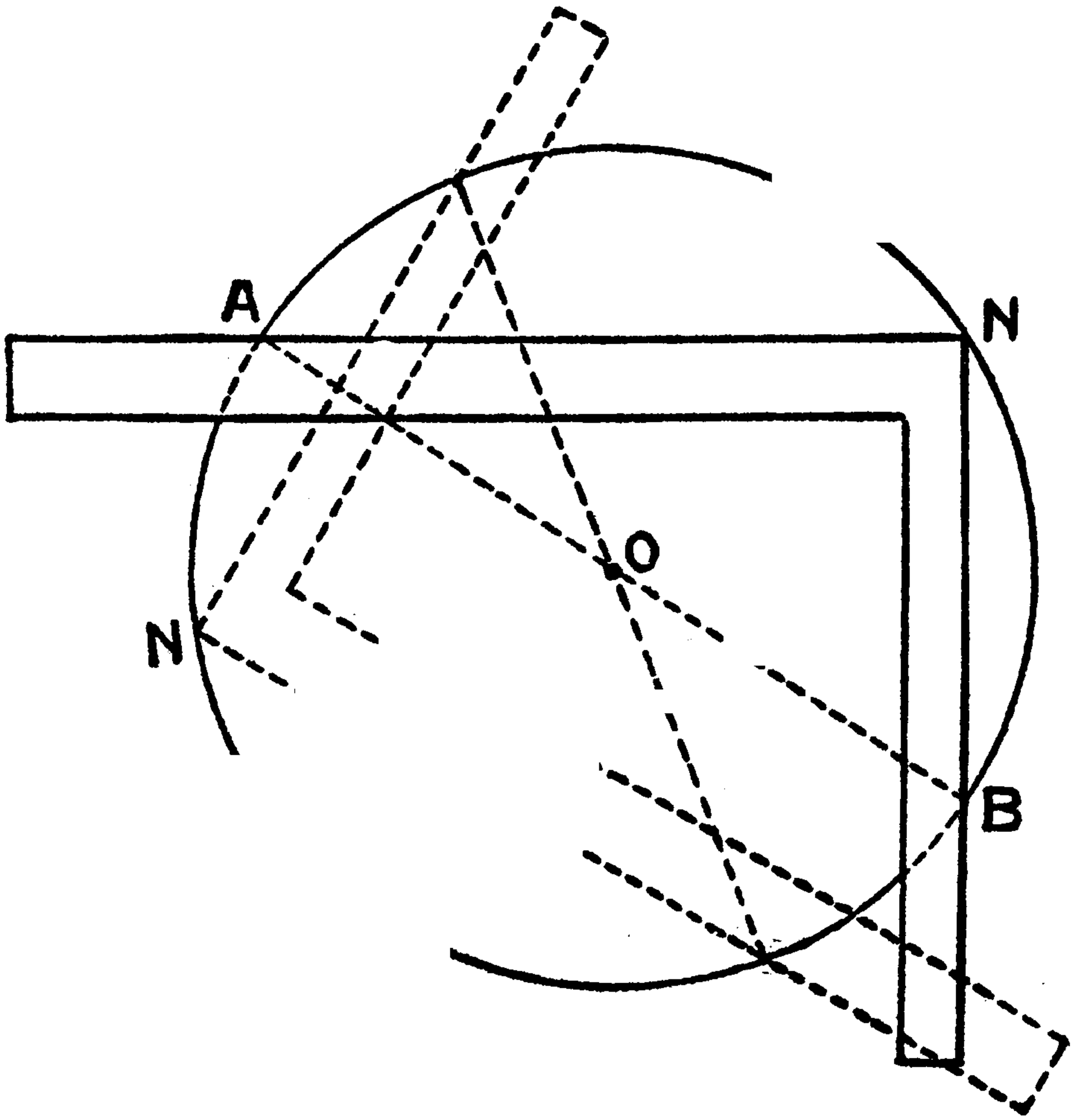

FIG. 149

crosses the line or where the lines intersect, as at X, there will be the center of the circle. This is a very useful rule, and by keeping it in mind the mechanic may very frequently save himself

much trouble, as it often happens that it is necessary to find the center of the circle, when the compasses are not at hand.

Another Quick Method of finding the center of a circle by means of the steel square is shown in Fig. 149. Let N N, the corner of the square, touch the circumference, and where the blade and tongue cross it will be equally divided; then move the square to any other place and mark in the same way and straight across, and where the line crosses A, B, as at O, there will be the center of the circle.

To Find a Square of Equal Area to a Given Circle, we set the bevel to $9\frac{3}{4}$ inches on the tongue, and 11 inches on the blade; then move the bevel to the diameter of the circle on the blade, and the answer will be found on the tongue. If the circumference of the circle is given, and we want to find a square containing the same area, we set the bevel to $5\frac{1}{2}$ inches on the tongue and $19\frac{1}{2}$ inches on the blade

To Obtain Circumference of Circle of Given Diameter.—There are quite a number of methods of obtaining approximate proportions of the diameter of circles to their circumferences. The true proportion, or. as it is sometimes expressed, the squaring of the circle, is one of those feats, like the discovery of perpetual motion, and is as far from being accomplished as ever. At any rate, it makes but little difference at this time to the operative mechanic, whether the circle can be squared or not, so long as he can get near enough

to the truth to satisfy the requirements at hand satisfactorily, and to aid him in this, the following method is shown of obtaining the circumference of circles when the diameter is given, by use of the square. Of course, as shown in the cut the rule will apply to circles of any reasonable dimensions.

Let A B, in Fig. 150, be a straight line, or the straight edge of a board; then apply the square as shown, placing the 16 inch mark on the blade at C, and the 5 inch mark on the tongue at D. See that the junctions of the blade and tongue of the square with the line A B, are accurately placed, for on this depends the truth of the results. Now, suppose we wish to ascertain the circumference of a circle whose diameter is 8 inches; commencing at the point, C, we space off the diameter, 8 inches, three times, on the line C O, as shown at 8″ 8″ 8″; then square down the line 8″ F, then C F will be the circumference of a circle whose diameter is 8. It will be seen, by dotted lines in the cut, that the circumference equals the diagonal of a rectangle whose sides are respectively 24 and 7 and 15-32 inches; so that by adopting these figures (24 and 7 and 15-32), it enables the operative to use the full length and capacity of the square. The better way however, is to work from a basis of 16 and 5, and draw the lines, C O and A B, to considerable length, so that they may be made available for dimensions beyond the range of the square. Now, let us suppose an instance where the circumference of a circle is wanted

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whose diameter is 10; we simply space off three tens, or thirty inches, on the line C O, which, in this case, is at K. Square down from K to R, and C R is the length sought.

Now, to prove this, let us proceed as follows: Diameter = 10 x 3.1416 = 31.4160, or nearly thirty-one inches and fifteen thirty-seconds of an inch. Now, if we measure C R, we will find that the

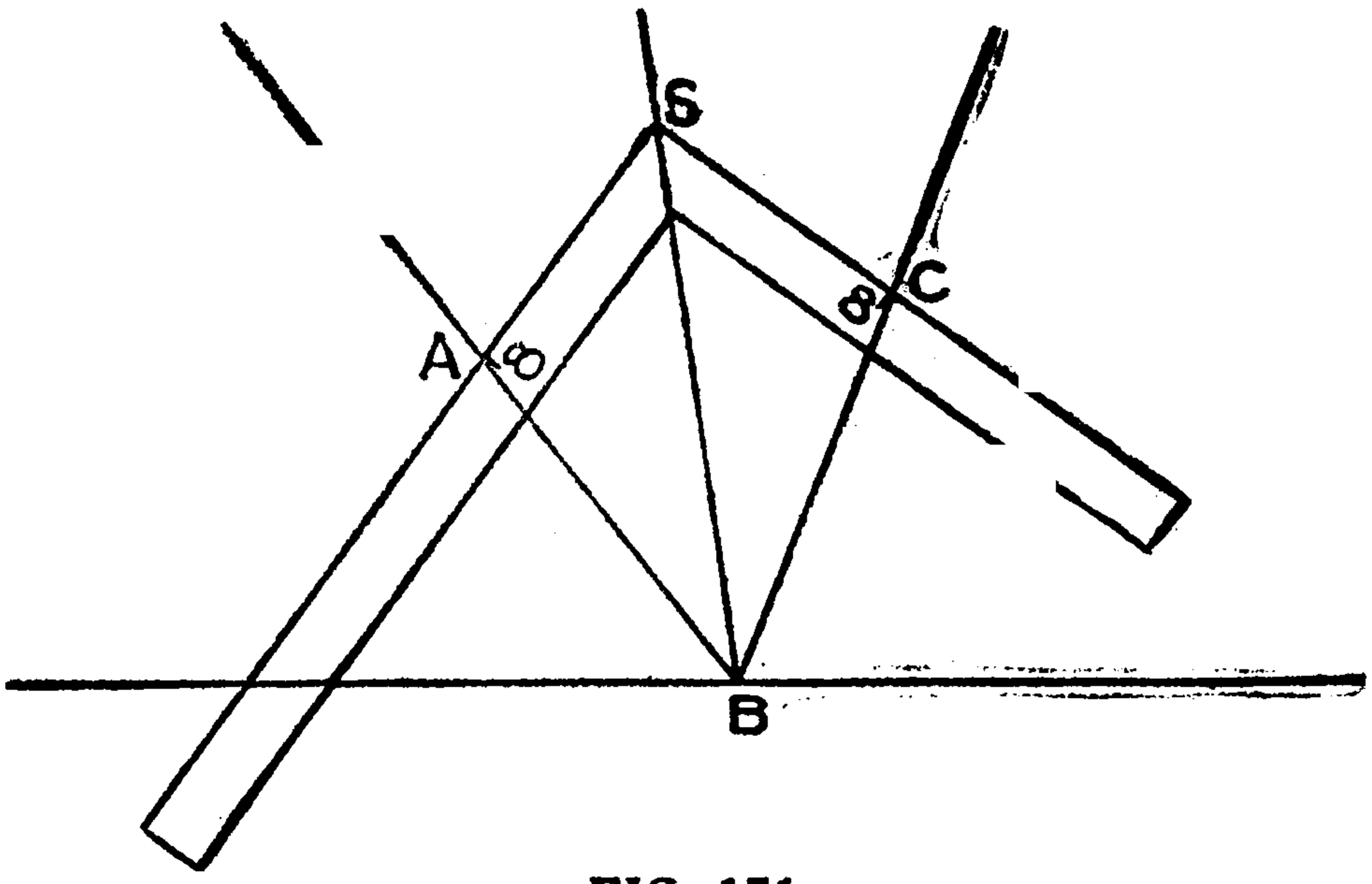

FIG. 151

distance is exactly 31.4160 inches, and is, therefore, the answer sought. It will be seen by these examples that the circumference of circles may be easily obtained when the diameters are known. So, also, may the diameters be found when the circumferences are known, for by laying off the circumference on the line A B, as C D in Fig. 150 for instance, and then applying the square as there exhibited, and dividing the distance from the

heel of the square to the point C into three equal parts. One of these parts is the diameter of the circle whose circumference equals the distance from C to D.

Method of Dividing Angles.—A B C, Fig. 151, is an acute angle. We wish to divide it. Measure up from B to A any distance, make B C the same distance, place the square on the points as shown on A and C, keeping the distance on the blade and tongue the same, then the heel or corner of the

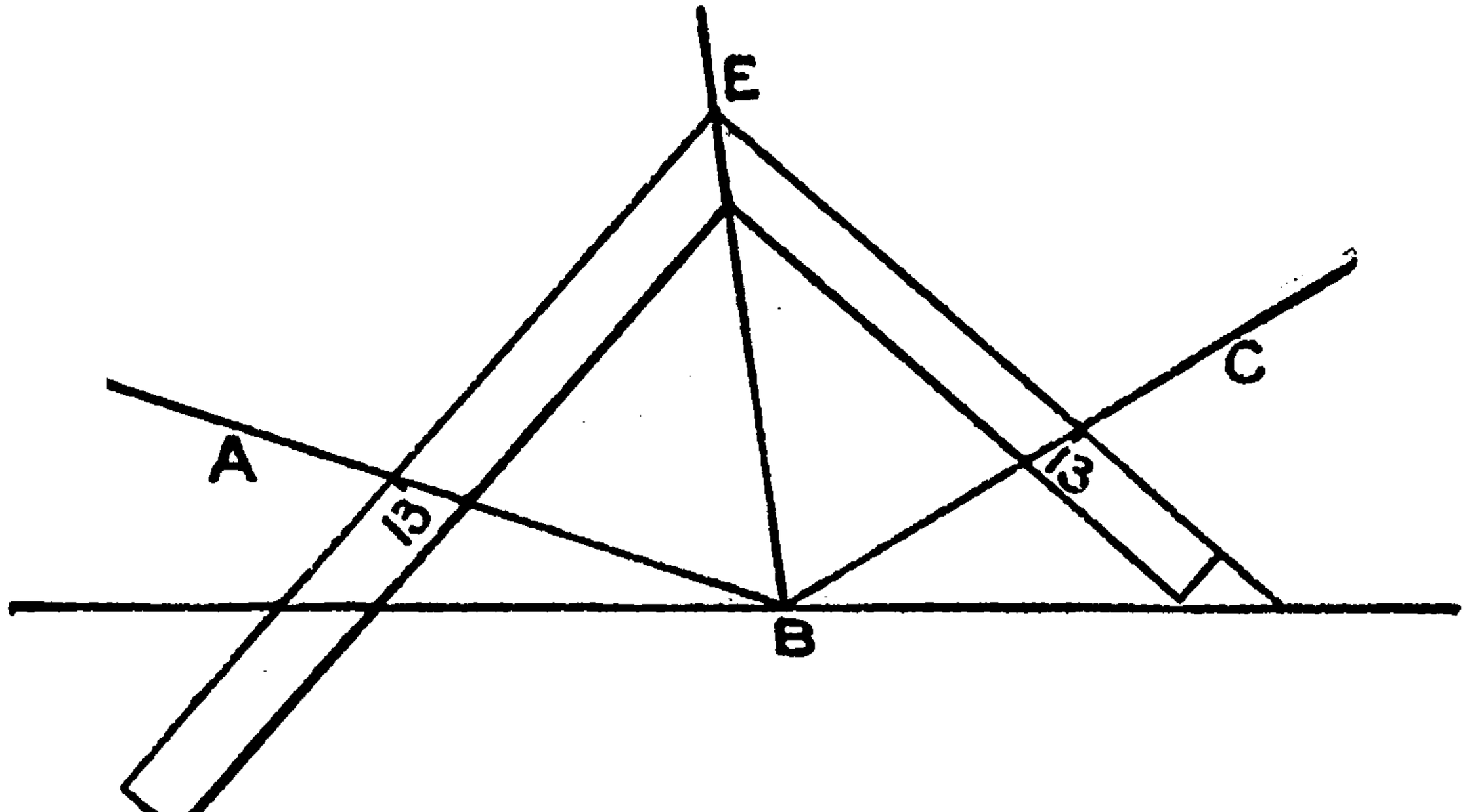

FIG. 152

square, S, will give the points through which to draw a line passing through the angle at B, and the division will be complete.

Again: Let Fig. 152 be an obtuse angle; make B A and B C equal. Apply square as shown, keeping equal distances on the blade and tongue at the points of contact A and C. The point E on the heel of the square will be one point from

which to draw a line through B, which forms the division of the angle.

In Fig. 153 we show a number of angles, which are treated same as the foregoing. At the junc-

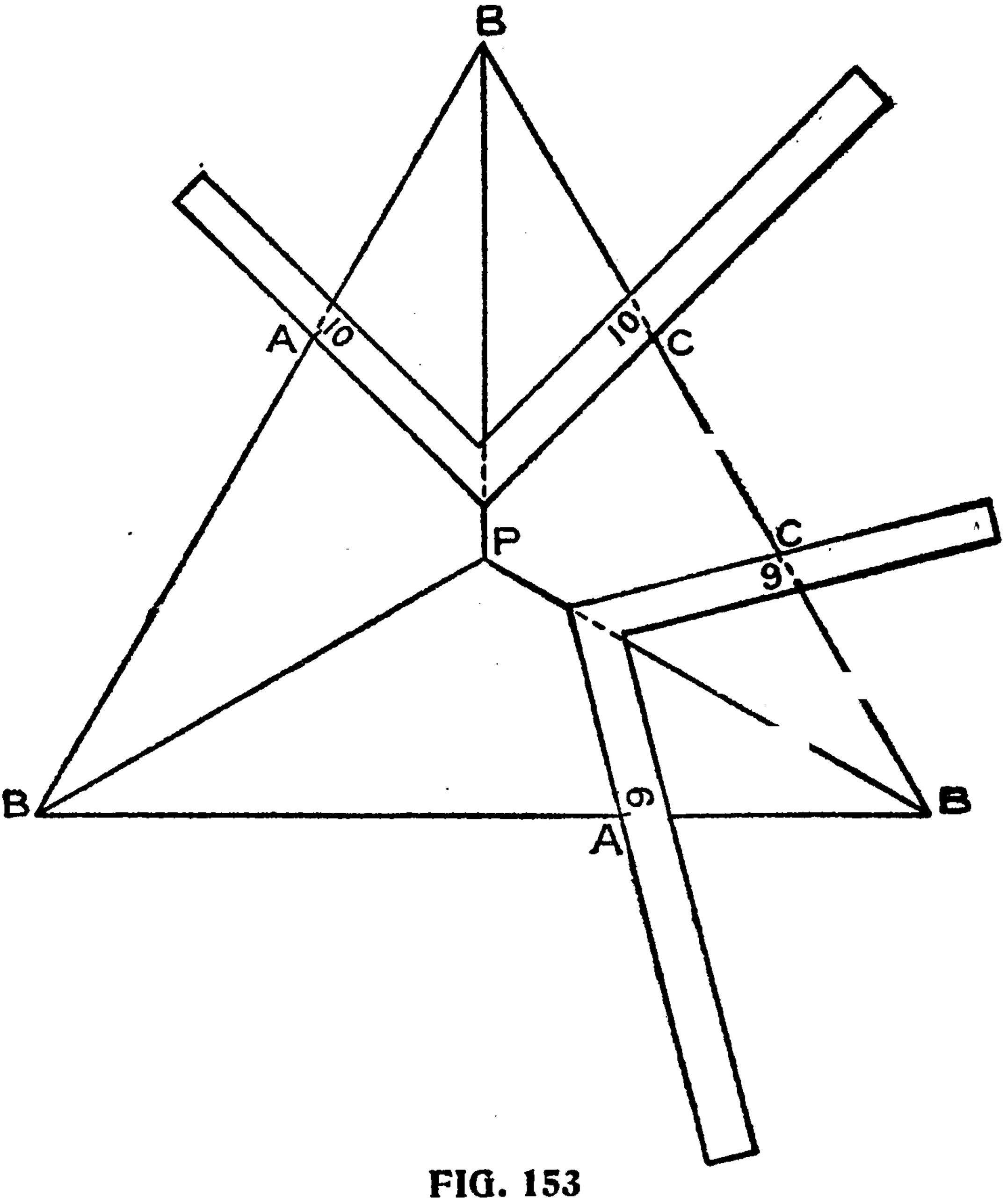

FIG. 153

tion of the lines drawn from the angles B B B, the center of the triangle is found at P.

This method of bisecting an angle is very use-

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tion may be equally divided by a proper use of the steel square.

To Form a Template or Set Square.—Suppose we want to find the angle 45 degrees on a board, we mark any two points A C, Fig. 155, on the edge of a board; apply the square as shown, keeping its sides on A C; then the distance on each side of the square being equal, measuring from its

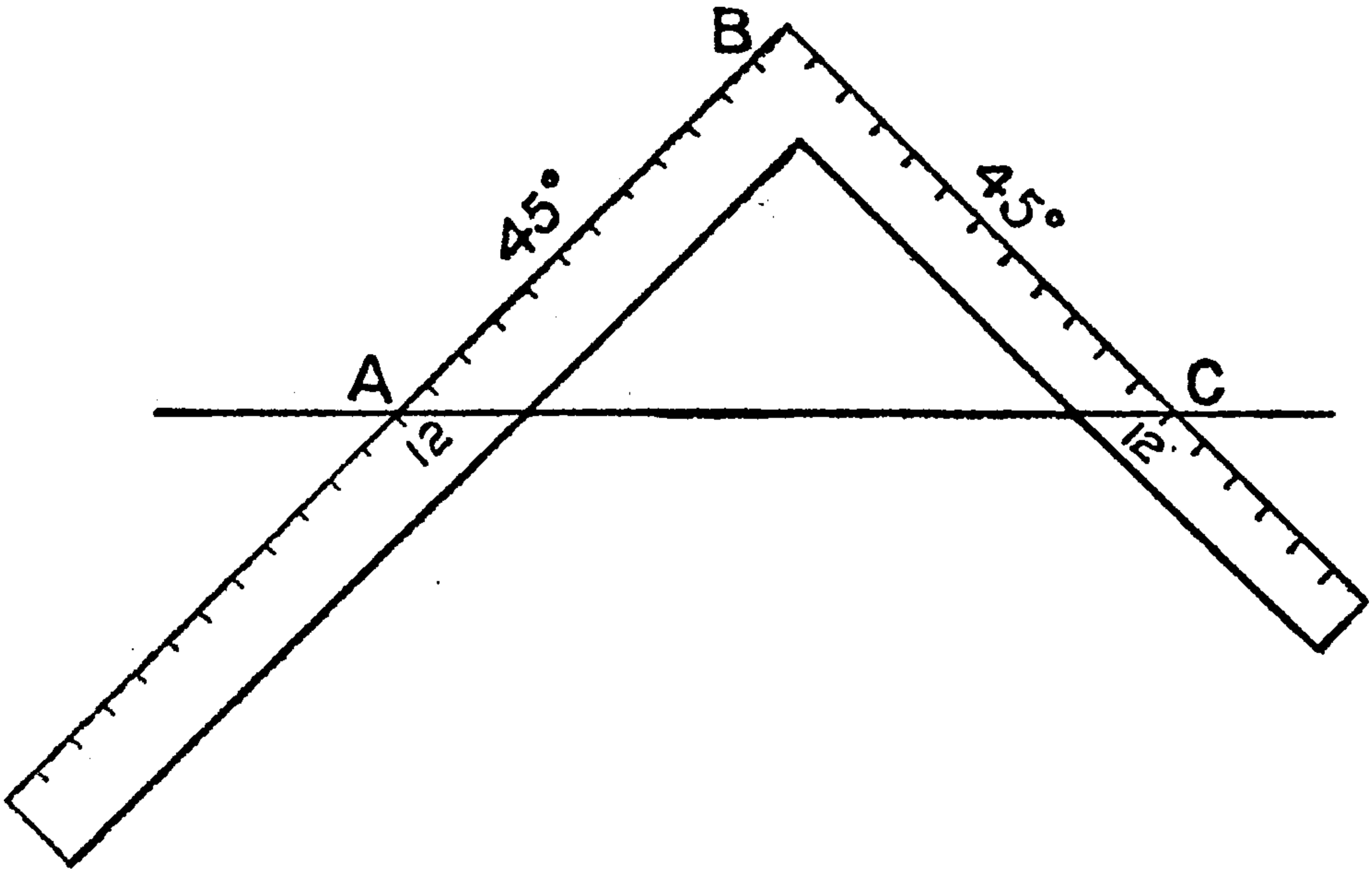

FIG. 155

heel or corner B gives the angle 45 degrees. If this portion be cut out it will form a templet or set square, which is very useful in drawing. The lines A B and C B are true miters, or angles of 45 degrees, with the line A C as their base.

In Fig. 156, A, B, C, R show the lines for forming a set-square having 60 degrees on the line C R, and 30 degrees on A R. This figure is formed with compasses, as follows: Make A C length of

base line; let B be half the distance between A C. From C B as centers and radius make the intersection at R, then by joining A R and C R the angles 30 degrees and 60 degrees are formed. This is the principle. To do all this with the

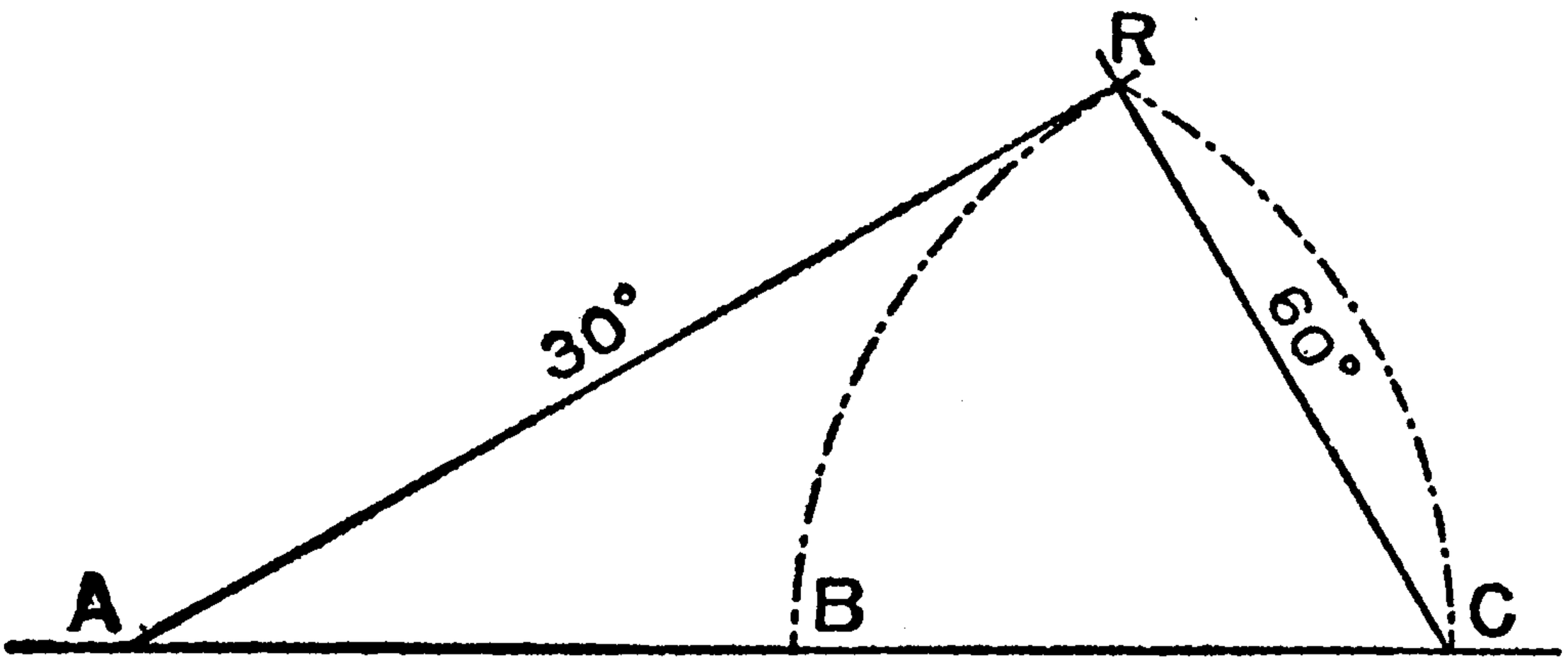

FIG. 156

square, simply take 23 inches on the blade and 13 inches on the tongue, and place these points on the line A B C, Fig. 157, and you have the angles at once. If the figure is greater than the square

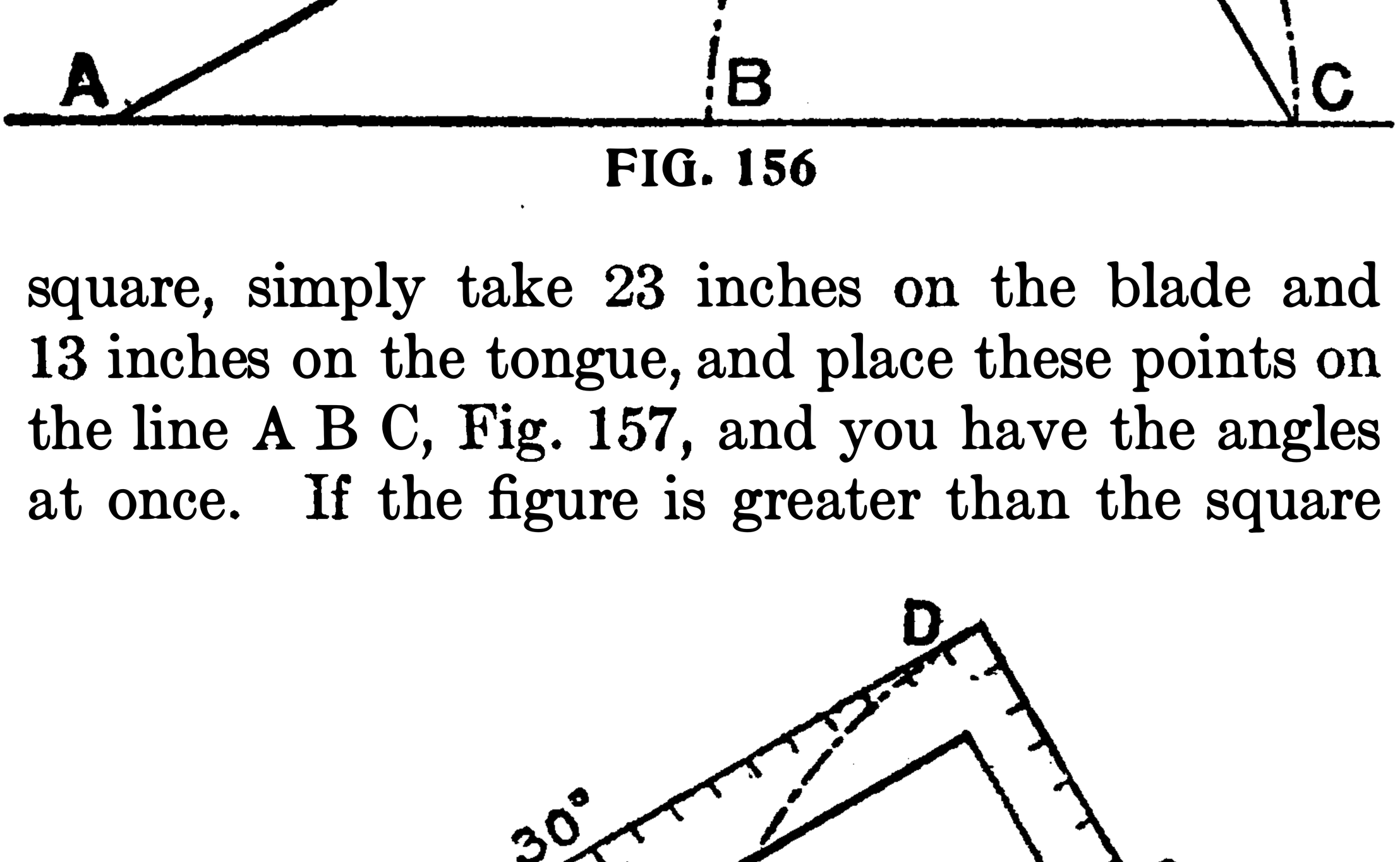

FIG. 157

can cover, then continue the line A D to the length required; then square down until the line cuts A B C, and the work is done. If a smaller figure is wanted, measure off on A D, or A B C, and square over.

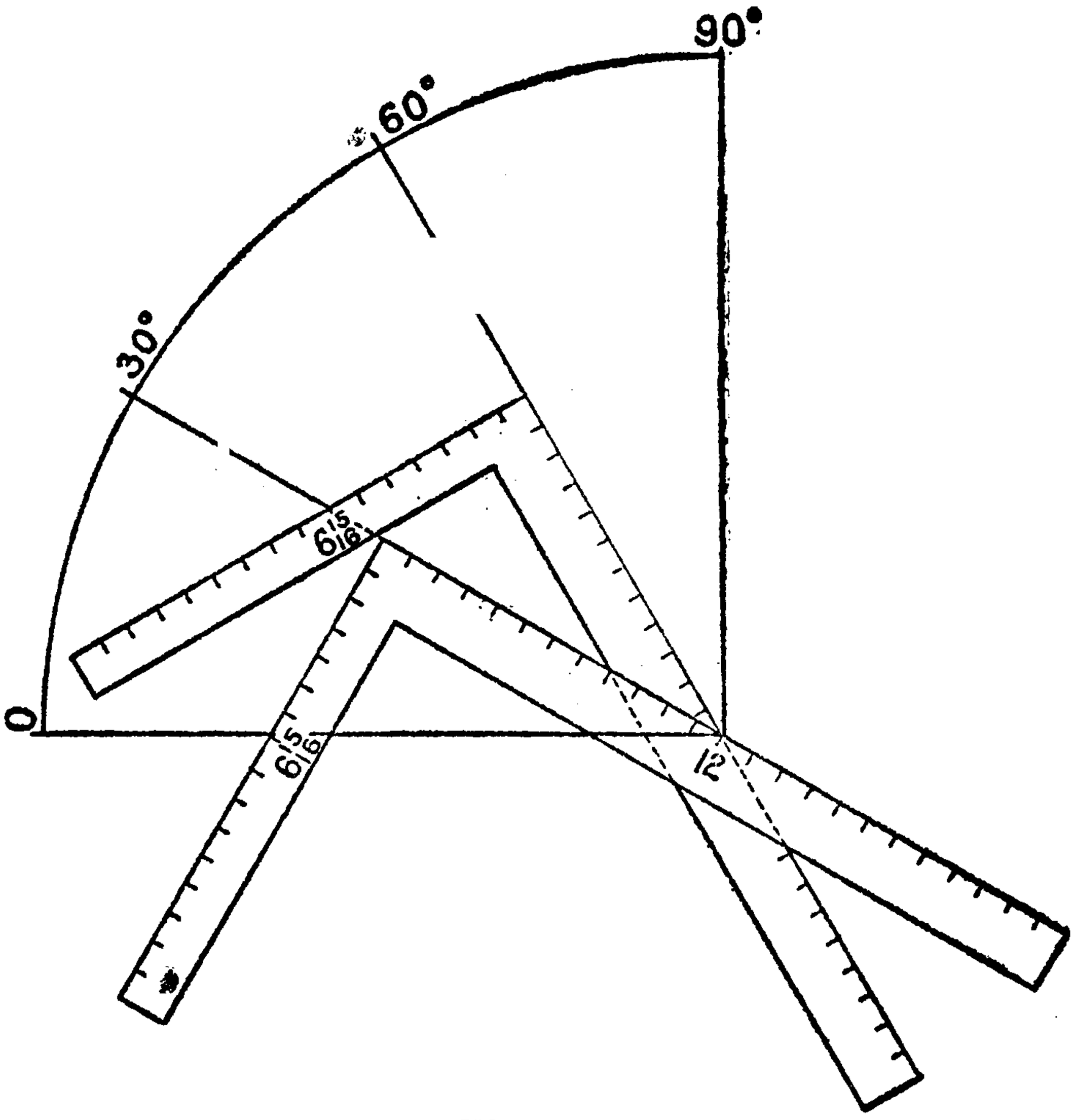

FIG. 158

In Fig. 158 we show a quarter of a circle trisected or formed into angles of 30, 60 and 90 degrees: 12 and 6 and 15-16 by the square will give 30 degrees and the remainder will be 60 degrees. These are things to remember, as the car-

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square at A, and let D on tongue be 7 and 15-32 inches. Take three diameters from A to C, and square down a line from C, cutting A D at E; then A E equals the circumference. A circle whose diameter is eight inches would have a circumference equal to the line from A to D by this rule. It will be seen by this that any right angle whose base is 24, and having an altitude of 7 and 15-32, forms a constant by which any circumference may be obtained by spacing three times the diameter on the line A B, and squaring down as at C, the hypothenuse being the required answer. The line A B may be continued indefinitely, being careful to retain the proper angle as shown in diagram.

Fig. 160 shows a method by which the circumference of a circle may be obtained from the diameter. This will be found very convenient in almost all the trades; particularly is it so for sheet-metal workers, carpenters, plasterers and coopers.

Describe a circle in some proportion to the actual work, say one inch to the foot; then apply the heel of the square at the center of the circle, as at A, then project the lines A B and A C as shown. Now connect the points where the radial lines touch the circle by the line B C, and from the middle point of this line draw the line D E to the circumference. To obtain the circumference of the circle, add to three times the diameter the distance D E, which will give the desired result practically correct.

In Fig. 161 we give a practical illustration. Suppose we have a circular tank, or a sheet-metal vessel of any sort that requires to be twenty feet in diameter. Draw a circle twenty inches in diameter. This is one inch to the foot; place the

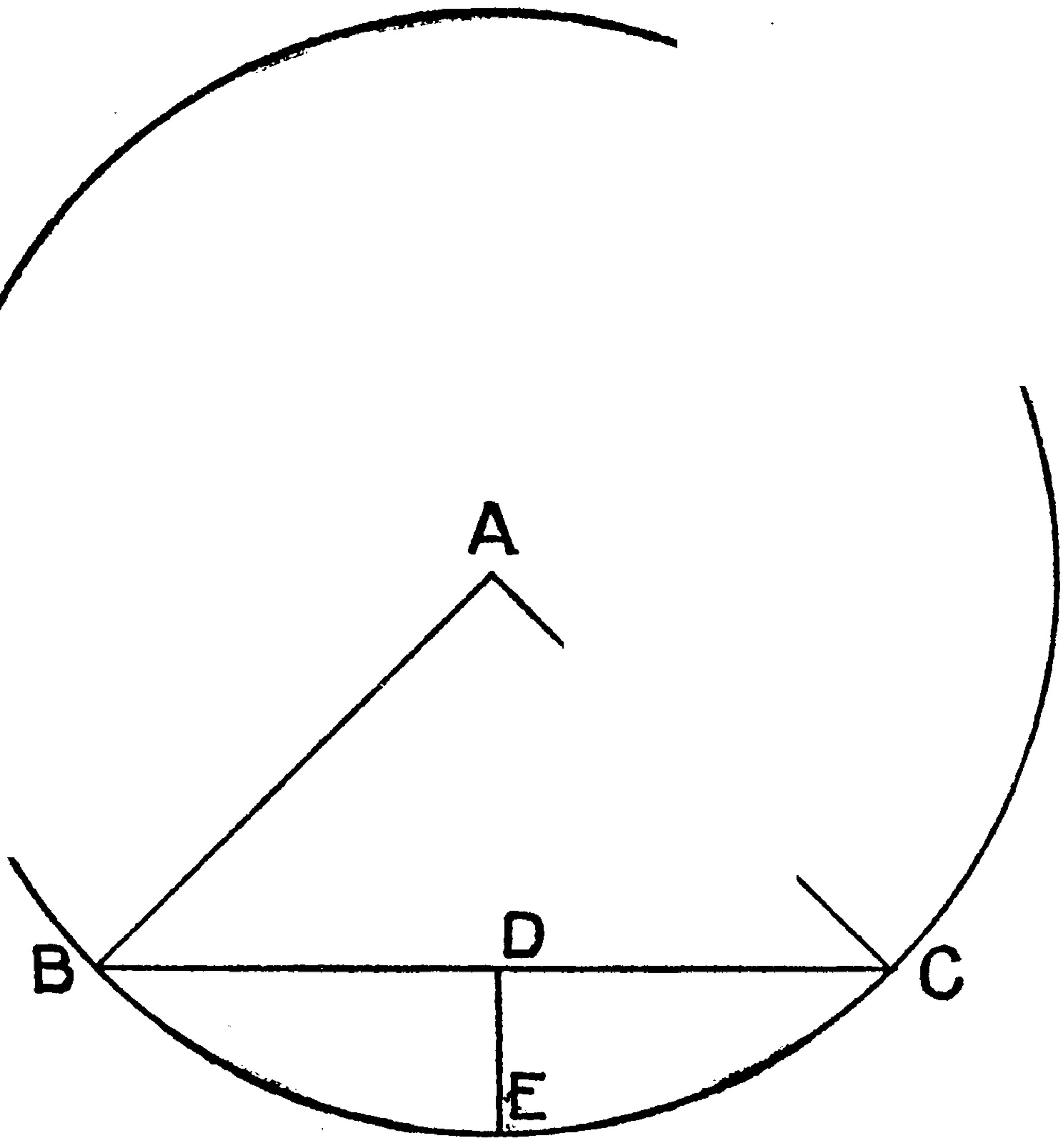

FIG. 160

square with the heel on the center as at A, draw lines along side blade and tongue as shown, cutting circumference, then at the junction of these lines draw a line same as B C in Fig. 160, then draw the short line from the center of the line B C, Fig.

160 and you have the circumference near enough for all practical purposes. It will be seen at once how useful this method may prove to the mechanic and how easily applied. For getting the length of hoops, or the number and breadth of staves

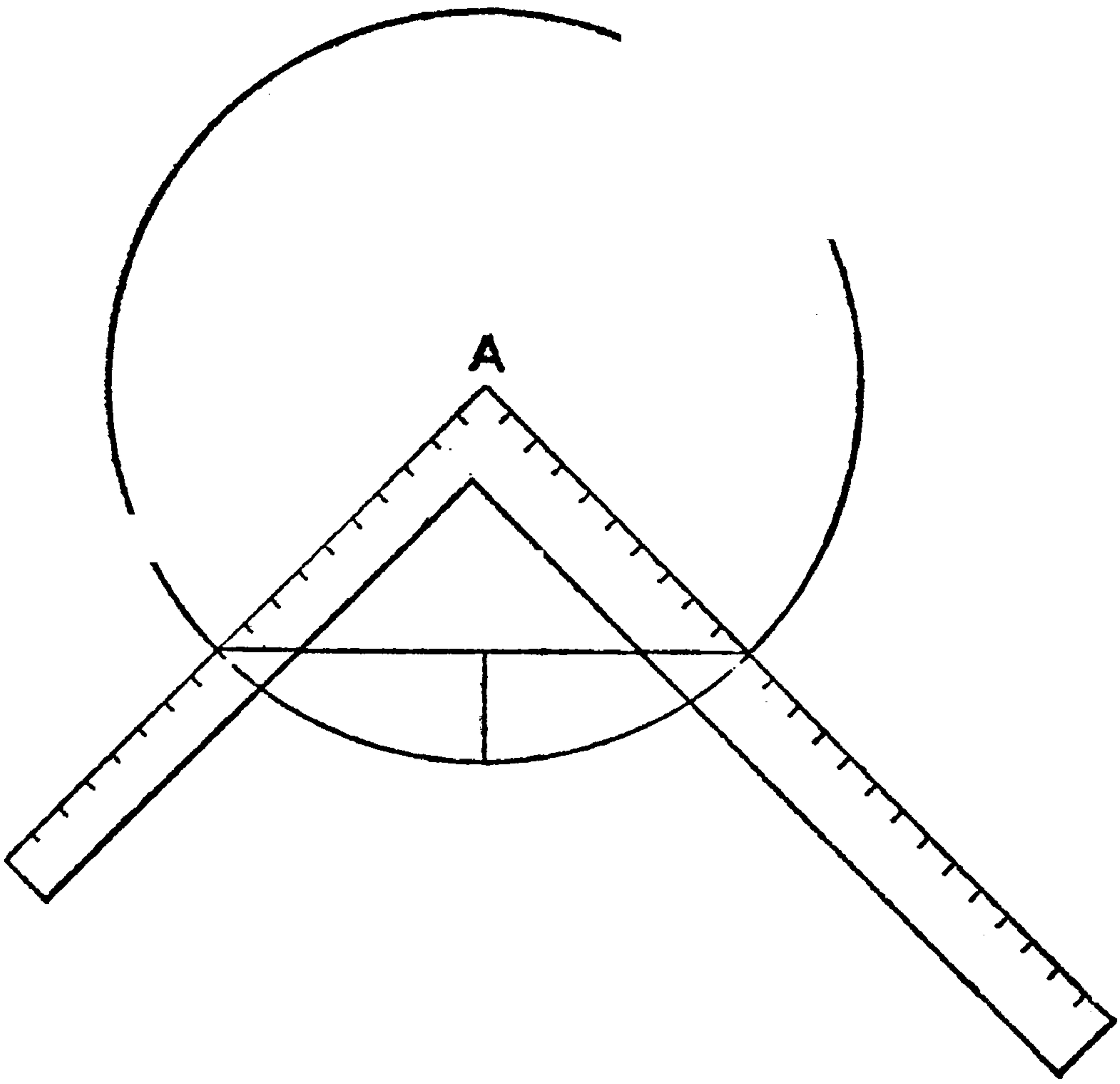

FIG. 161

for a circular tub, it will prove quite a useful method.

To Describe a Circle with the Aid of the Steel Square.—This may be accurately done provided the diameter of the circle does not exceed the length of the shorter member of the square.

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justment is obtained by making the distance, hl, equal to the semi-axis minor, and the distance l k, equal to the semi-axis major.

To Describe a Parabola.—Fig. 164 shows a method of describing a parabola by means of a

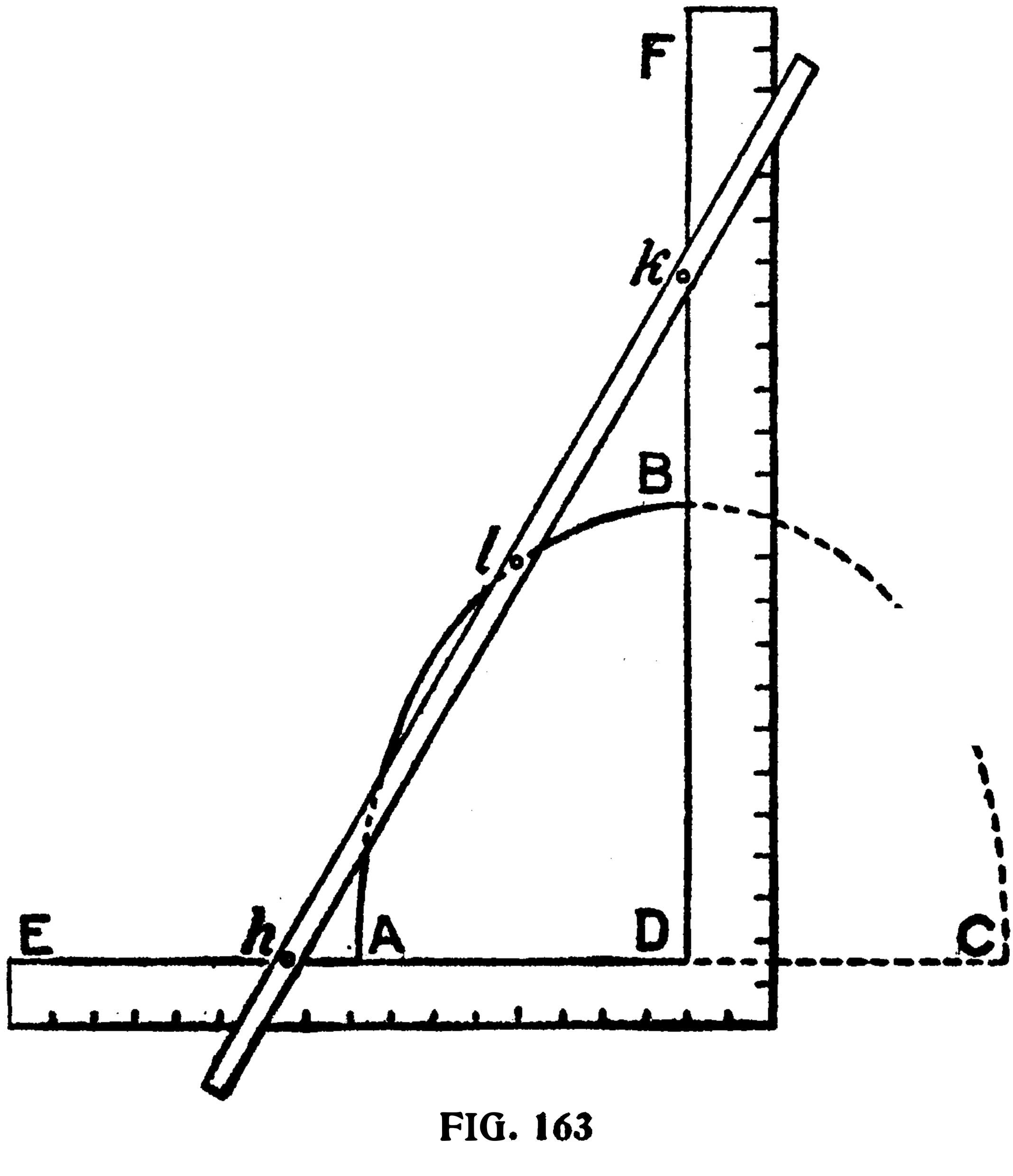
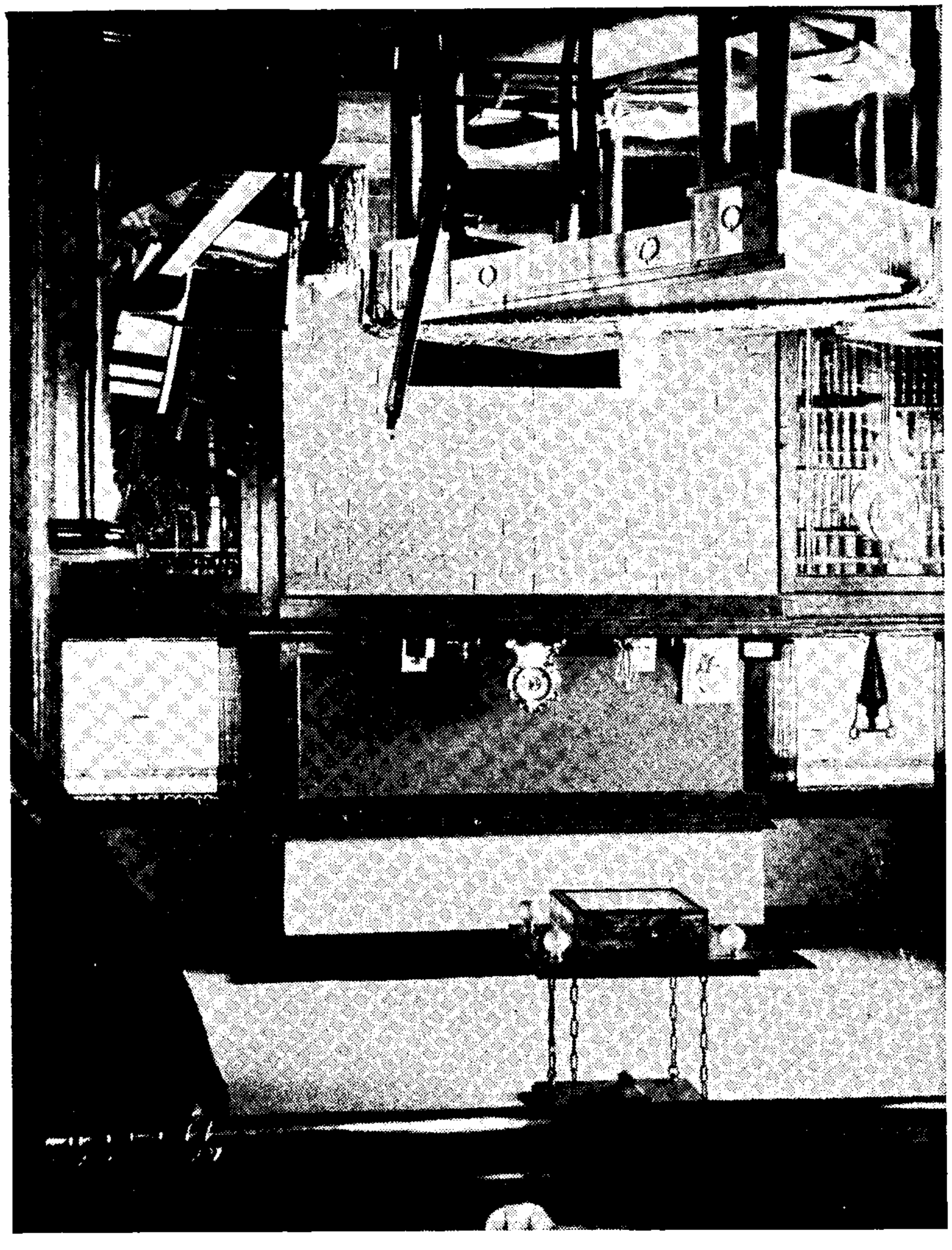
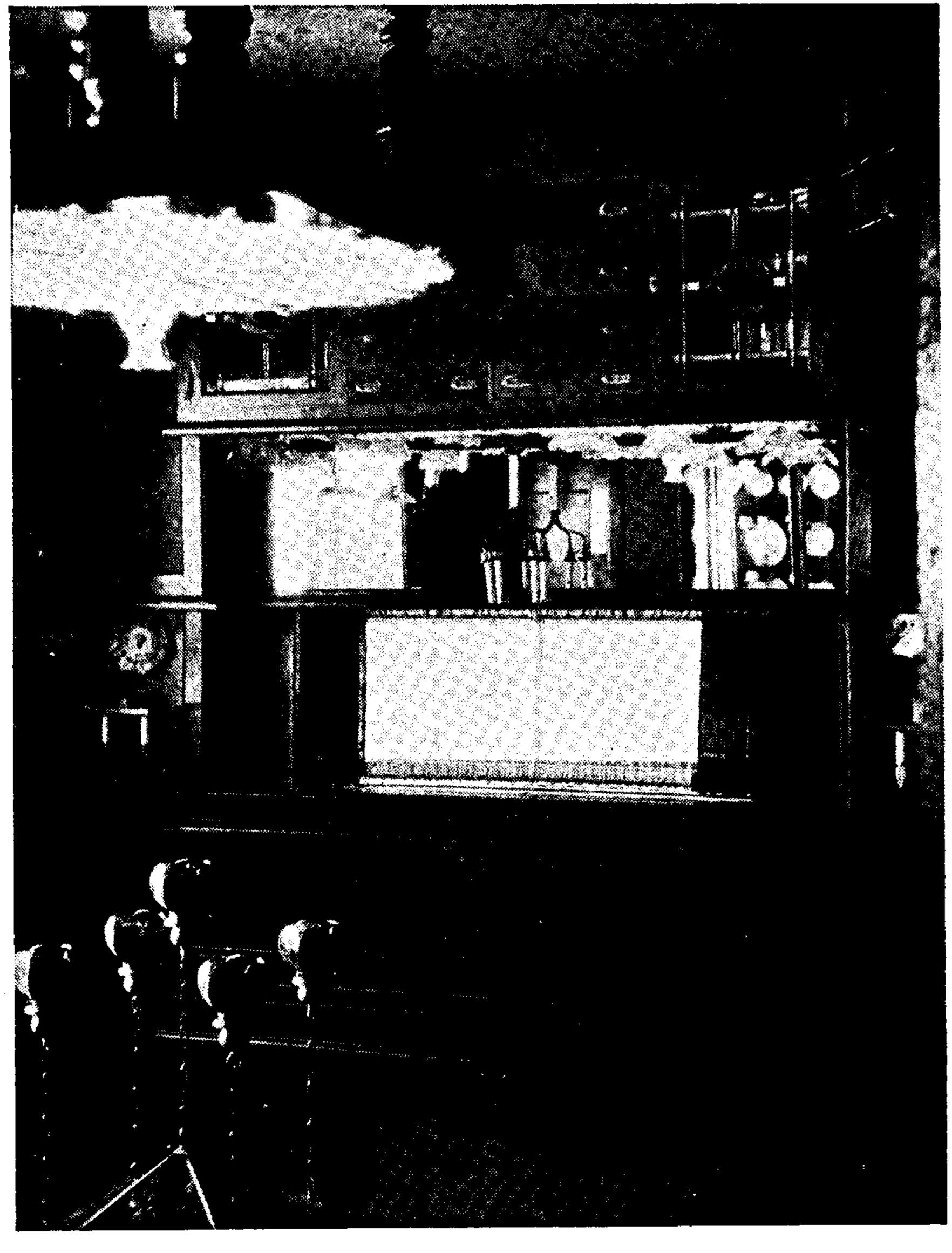


FIG. 163

straight rule and a square, its double ordinate and abscissa being given. Let A C be the double ordinate, B the abscissa. Bisect D C in F; join B F, and draw F E at right angles to B F, cutting the axis





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length from the suspending point; and a weight of 10 lbs. is suspended from the shorter arm, and it is required to know what weight will be required to suspend on the long arm to make it balance. Set a bevel on the blade of the square at 13 inches and the other end of the bevel on the 9 inch mark on tongue of square, then slide the bevel from 13 inches to 10 on the blade of square, and the answer will be found on the tongue of the square. It is easy to see how this rule can be reversed so that a weight required for the shorter arm can be found.

To Make a Semicircular Groove.—Sometimes the workman may have a semicircular groove to make, either as a pattern for casting or as a moulding of some sort. Now it is a well known geometrical fact that the angle within a semicircular circumference is a right angle; this being admitted, it may be taken advantage of in making such hollow forms as we have mentioned, and which we illustrate by the Fig. 165. The curve or semicircle may be worked out by a plane or other instrument, and to prove the correctness of the work, the steel square may be applied as shown. If the square touches at only two points, then the groove is not deep enough, or else it is too deep, in which case the operator must remove more stuff from the groove, or from the flat surface of the work, if permissible. By giving the square an oscillating motion, so as to make the corner sweep the entire surface of the curve, the accuracy of the work may be ascertained whenever the square is applied.

In this instance the square may be used as a templet, and the advantages of it in such cases are that it may be used in any sized semicircular groove, thus saving a multiplication of templets. This principle may be extended further, as it is equally applicable to a hollow hemisphere as to a hollow semicylinder, which makes the knowledge of this fact of great value to wood or metal

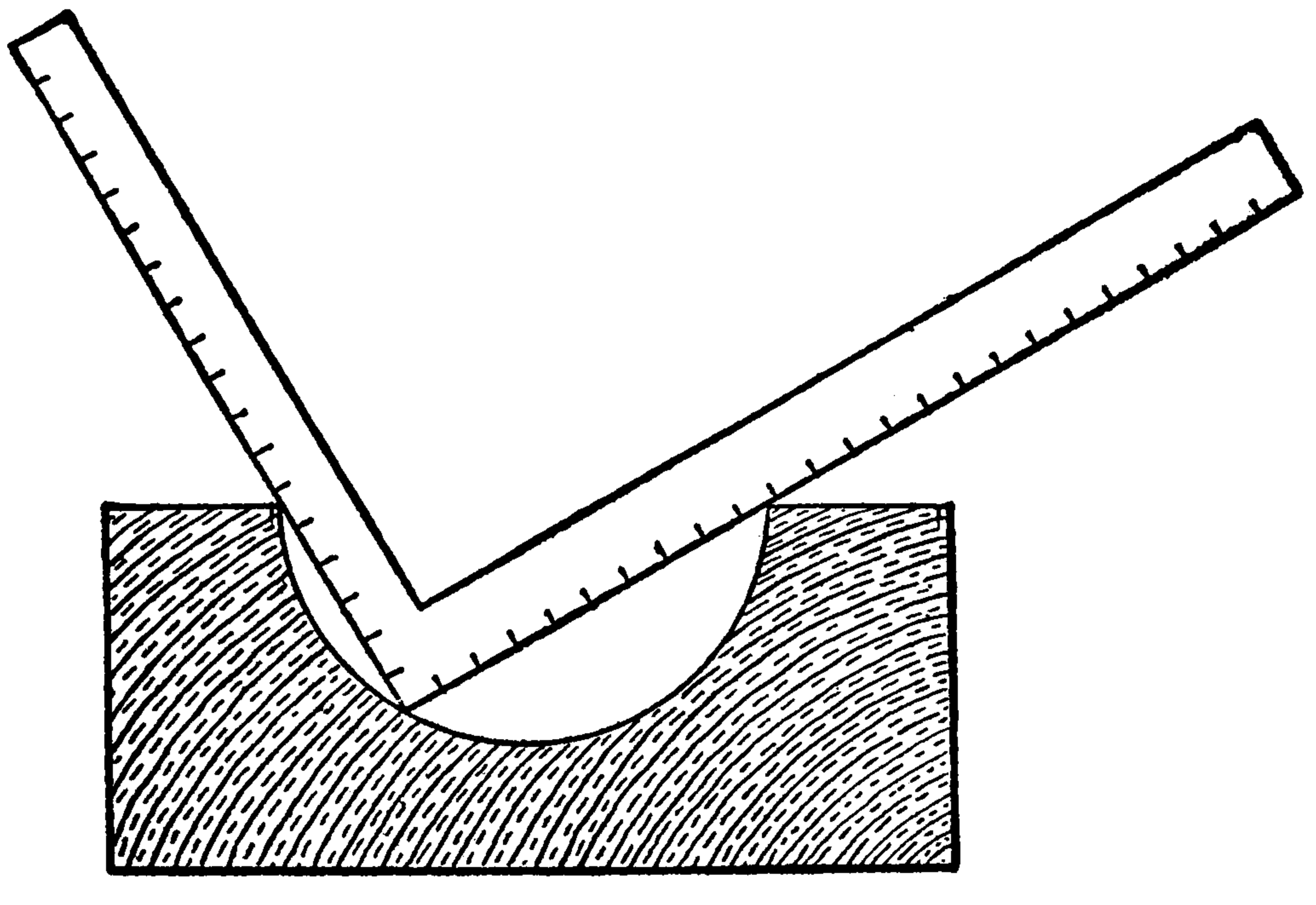

FIG. 165

turners, as it can be easily seen that a hollow hemisphere must be nearly true if the cutter or heel of the square touches every point, and the blade and tongue lie on the exact diameter. The operator can apply this principle to many cases, if he is at all ingenious.

To Cut for Pitched Covers.—Here is a little problem that may come into use on many occas-

ions: Suppose we want to cut a piece of sheet metal, paper or thin wood so that it may form a cone, or a cover for a vessel of some sort; say the pitch or height at center is to be four inches, and the diameter of the base sixteen inches. Lay off the pitch on the tongue and half the diameter

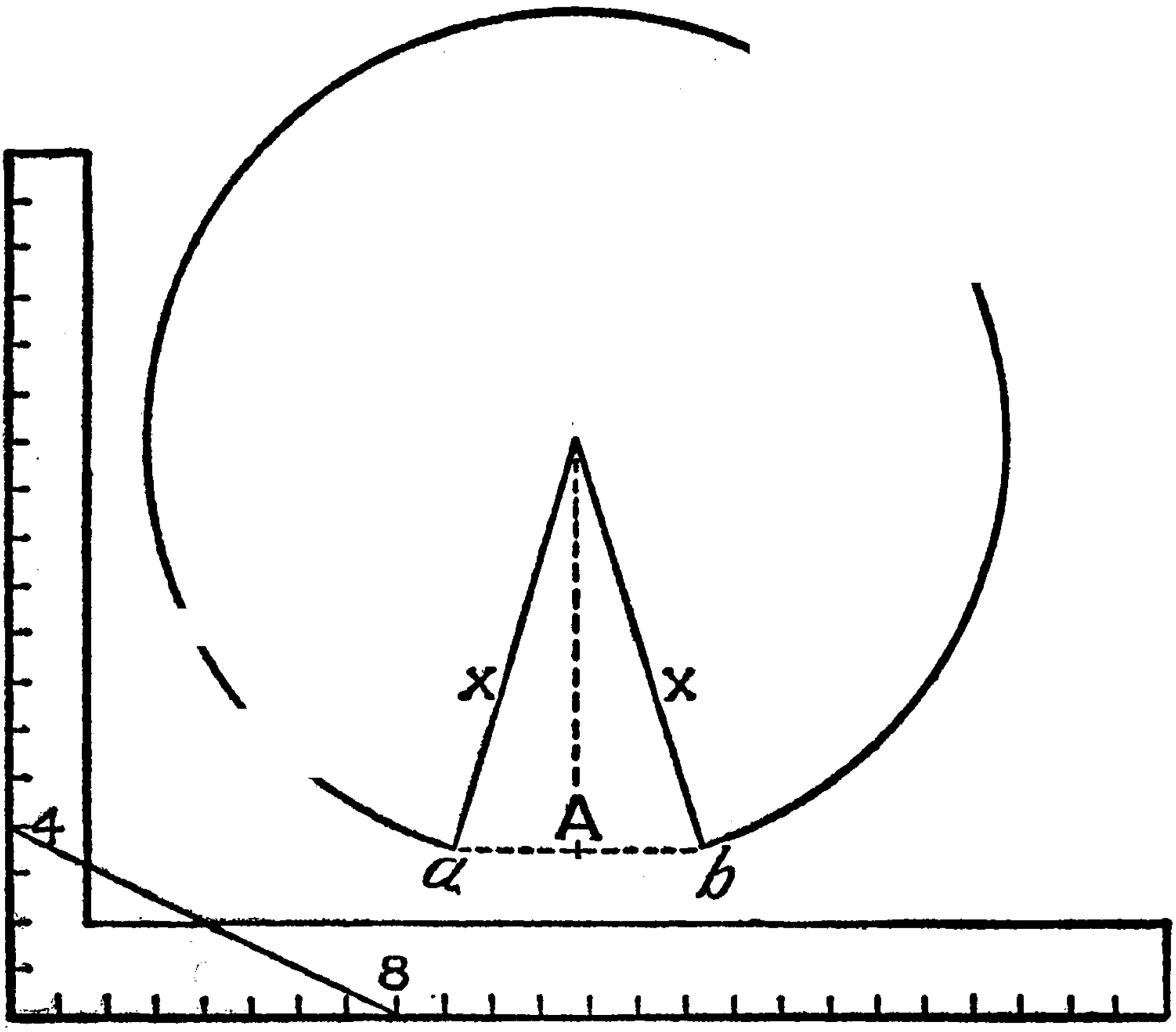

FIG. 166

on the blade. The diagonal, from 4 to 8, as shown in Fig. 166, gives half the diameter of the circle, to which set your compasses. Describe a circle as at Fig. 166, draw a line from the center as shown, square off from A, on each side three-tenths of the radius, ending at a, and b. The

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a miter, or equal joint, could be laid off by using the square.

The matter is simple, but the many inquiries that have been received induce us to give a few

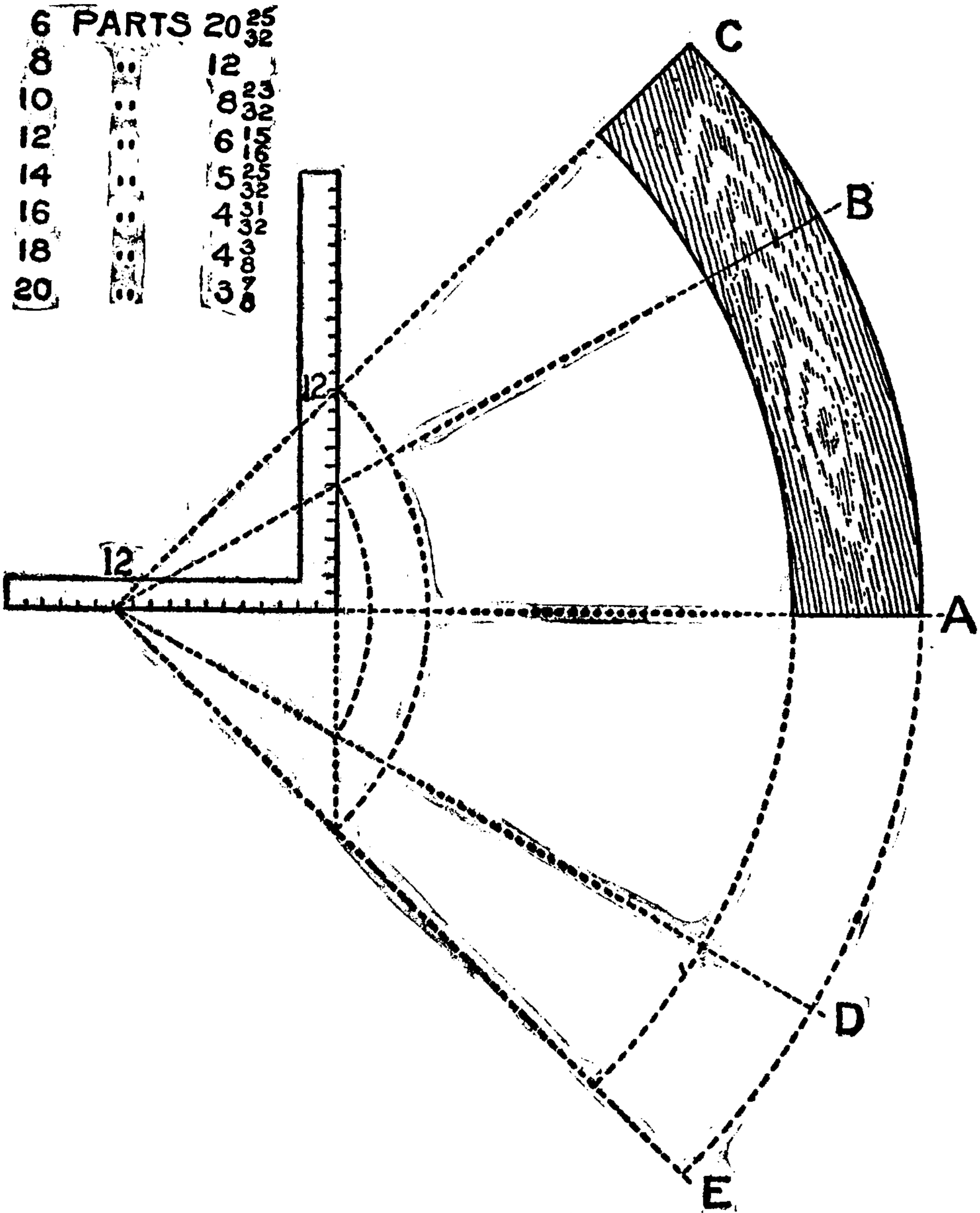

FIG. 167

examples of the manner in which advanced workmen generally accomplish this end. Let Fig. 168

represent an oblique angle formed by two parallel boards. To obtain the joint A, space off equal

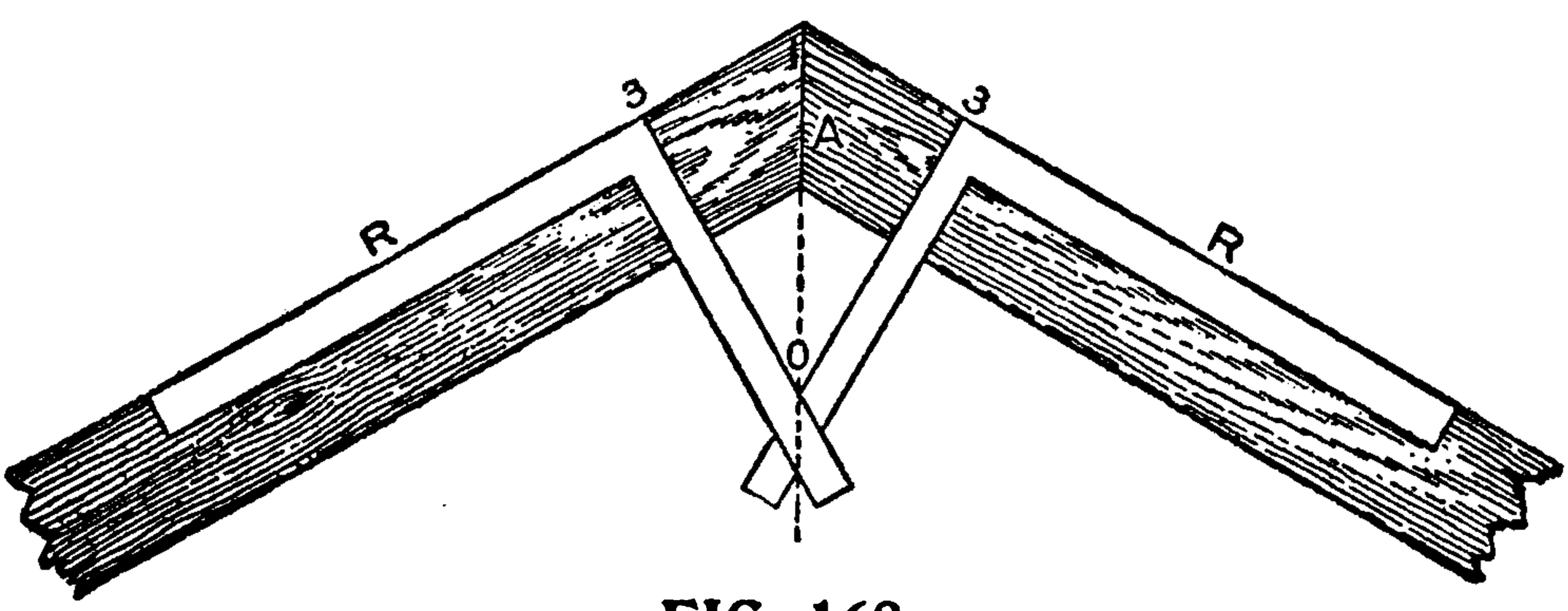

FIG. 168

distances from the point 1 to 3, 3, then square over from the lines, R, R, keeping the heel of the square at the points 3, 3. At the junction of the lines

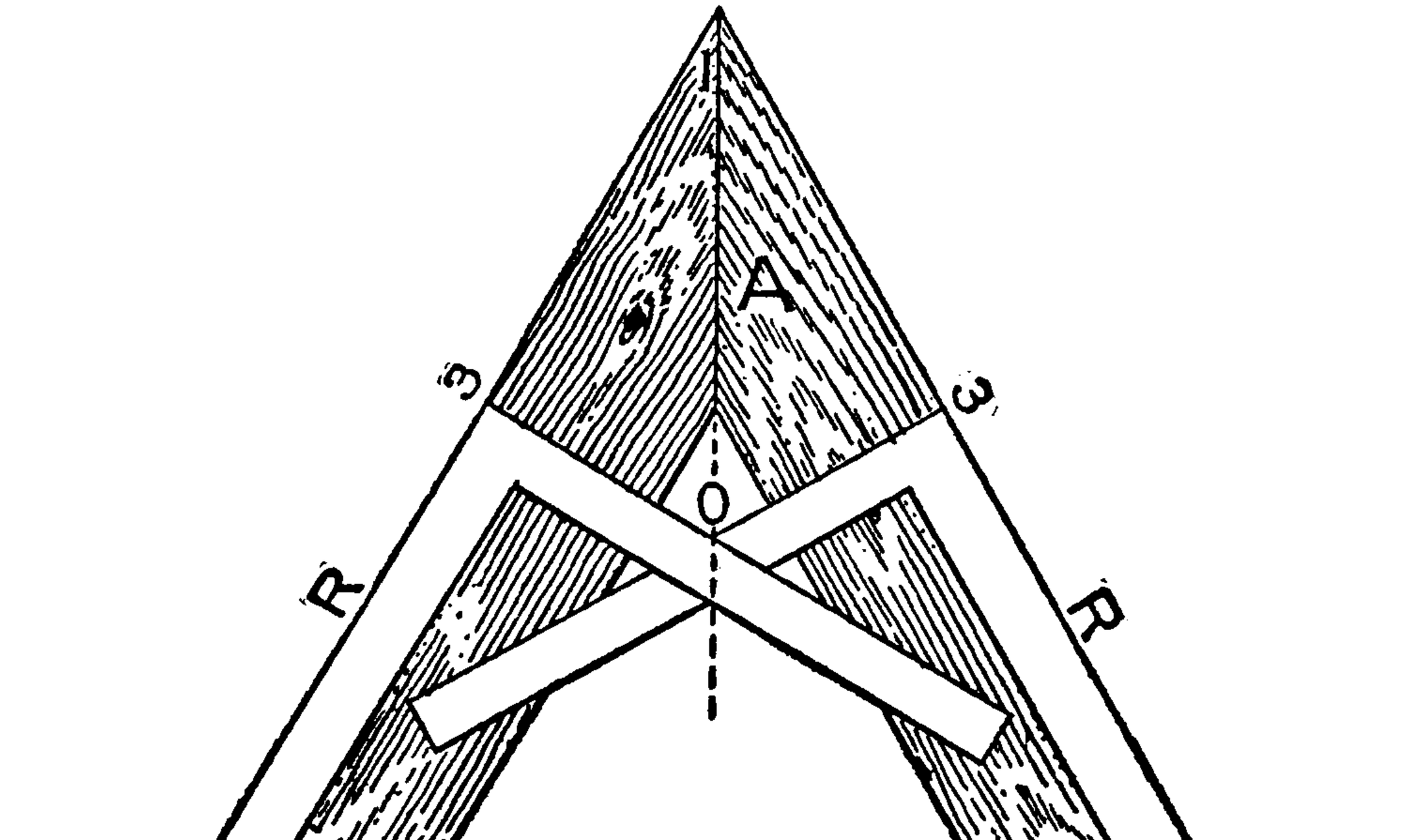

FIG. 169

formed by the tongues of the squares at O will be the point to take on the tongue, and $\frac{1}{8}$ on the blade. The latter will give the joint line, A, as defined.

To Find the Line of Juncture for an Acute Angle, we proceed as follows: Fig. 169 represents two parallel boards; 1 the extreme angle, 3, 3 equal distances from the angle 1 and are the points where the heel of the square must rest to form the lines O, 3; O shows the junction of the lines formed by the tongues of the squares, and then proceed as in the previous example.

It will be seen, by these two examples, that the bevel of a junction at any angle may be obtained by this method.

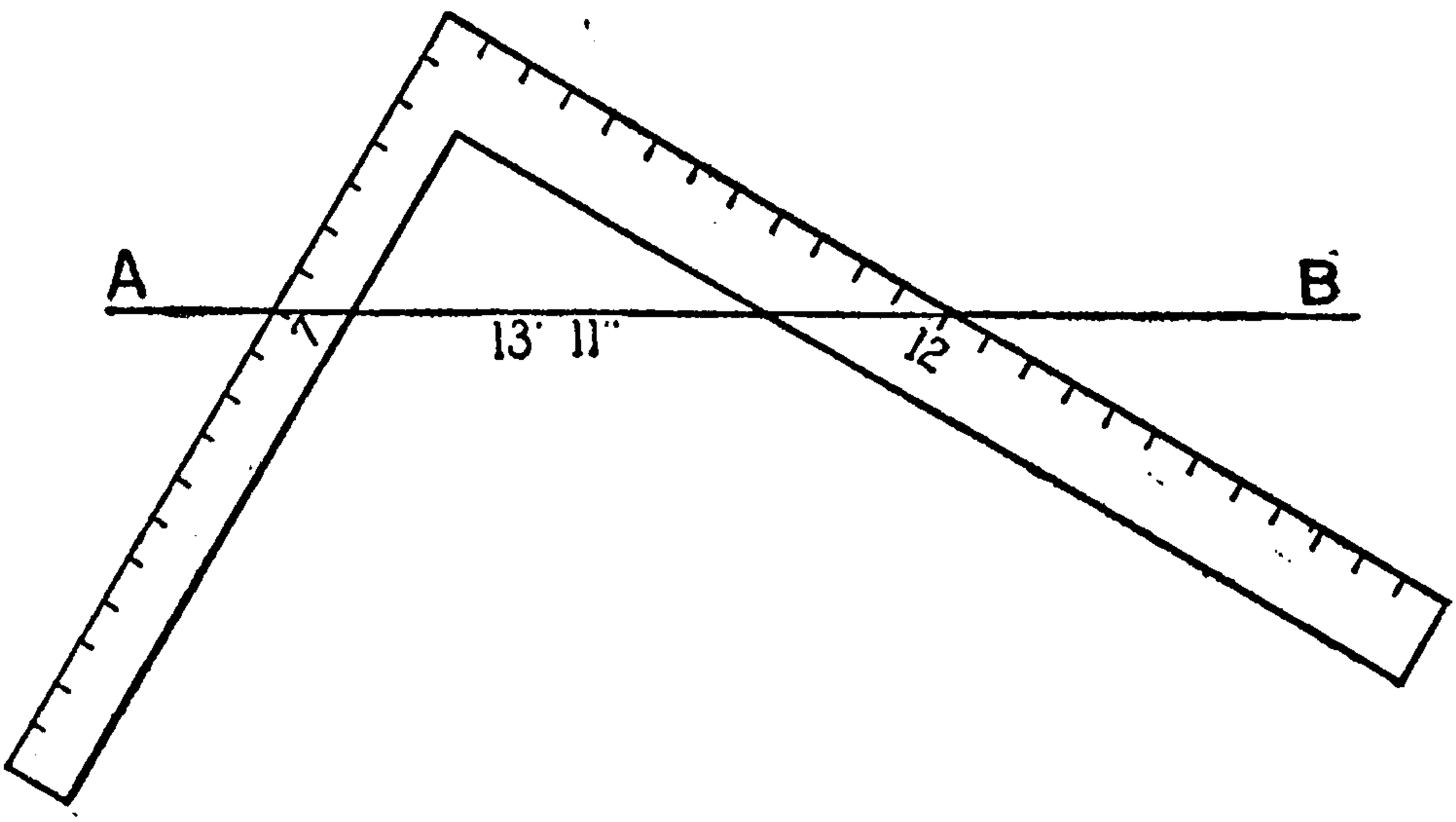

FIG. 170

To Find the Length of Braces and Other Timbers.—Sometimes, when estimating on work, it becomes necessary to get the length of braces and other timbers, that would require considerable fig-

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Again: Take a piece of timber twelve inches square, as in Fig. 172; take twelve inches on the blade and tongue from A to B, and A to C, mark at the point A, operate similarly on the opposite edge, and the marked points will be guides for

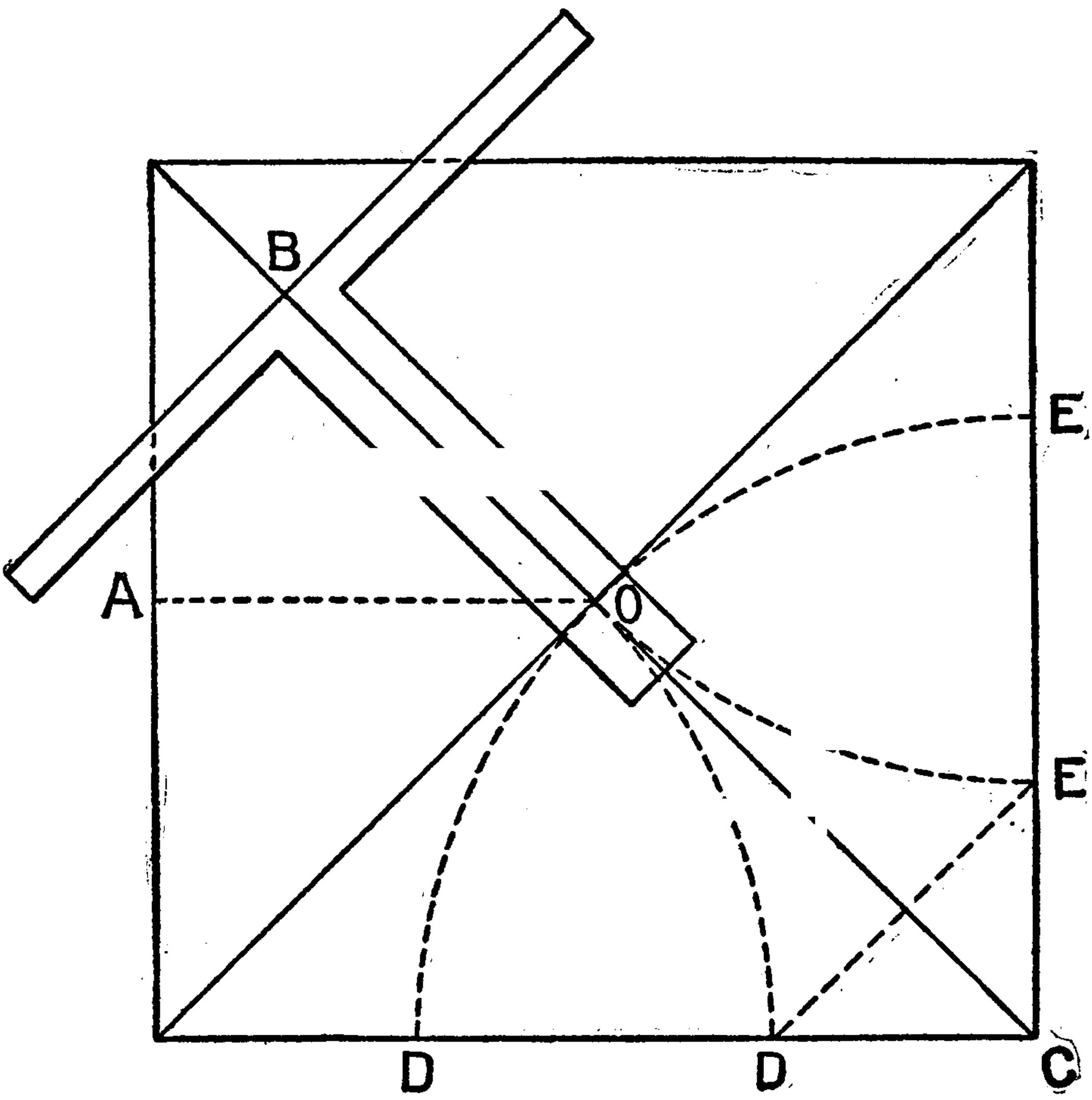

FIG. 171

gauge-lines for the angles forming an octagon. The remaining three sides of the timber can be treated in the same manner.

These points can be found with the carpenter's rule as follows: Lay the rule on the timber, partly

opened, as shown in the cut, prick off at the figures 7 and 17 as at A and B, and these points will be the guides for the gauge lines. The same points

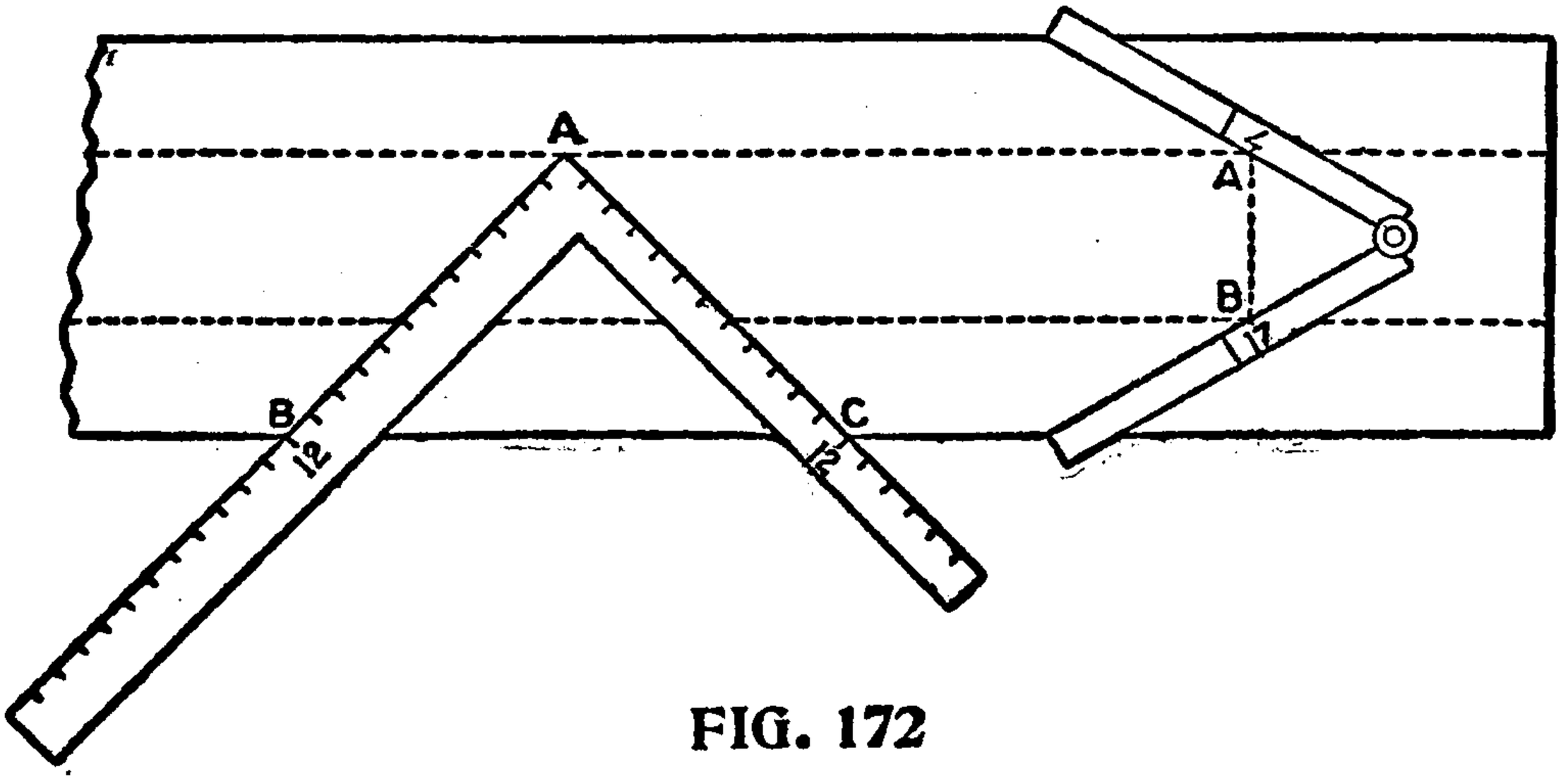

FIG. 172

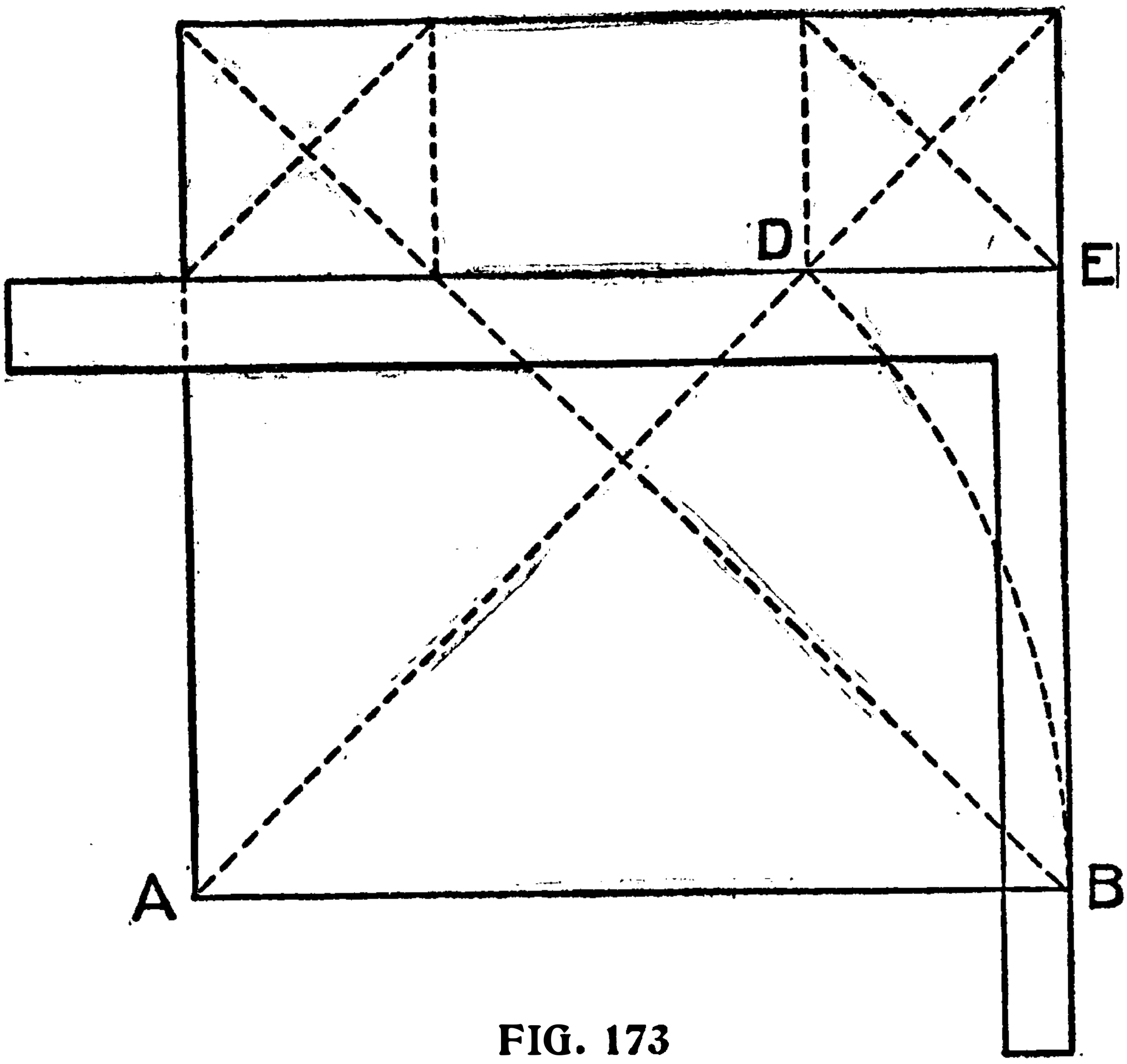

FIG. 173

can be found by laying the square diagonally across the timber and pricking off 7 and 17.

To Make a Moulder's Flask Octagonal, proceed as follows: The flask to be four feet across. Multiply 4x5 (as an octagon is always nearly as 5 to 12), which gives 20; divide by 12, which gives

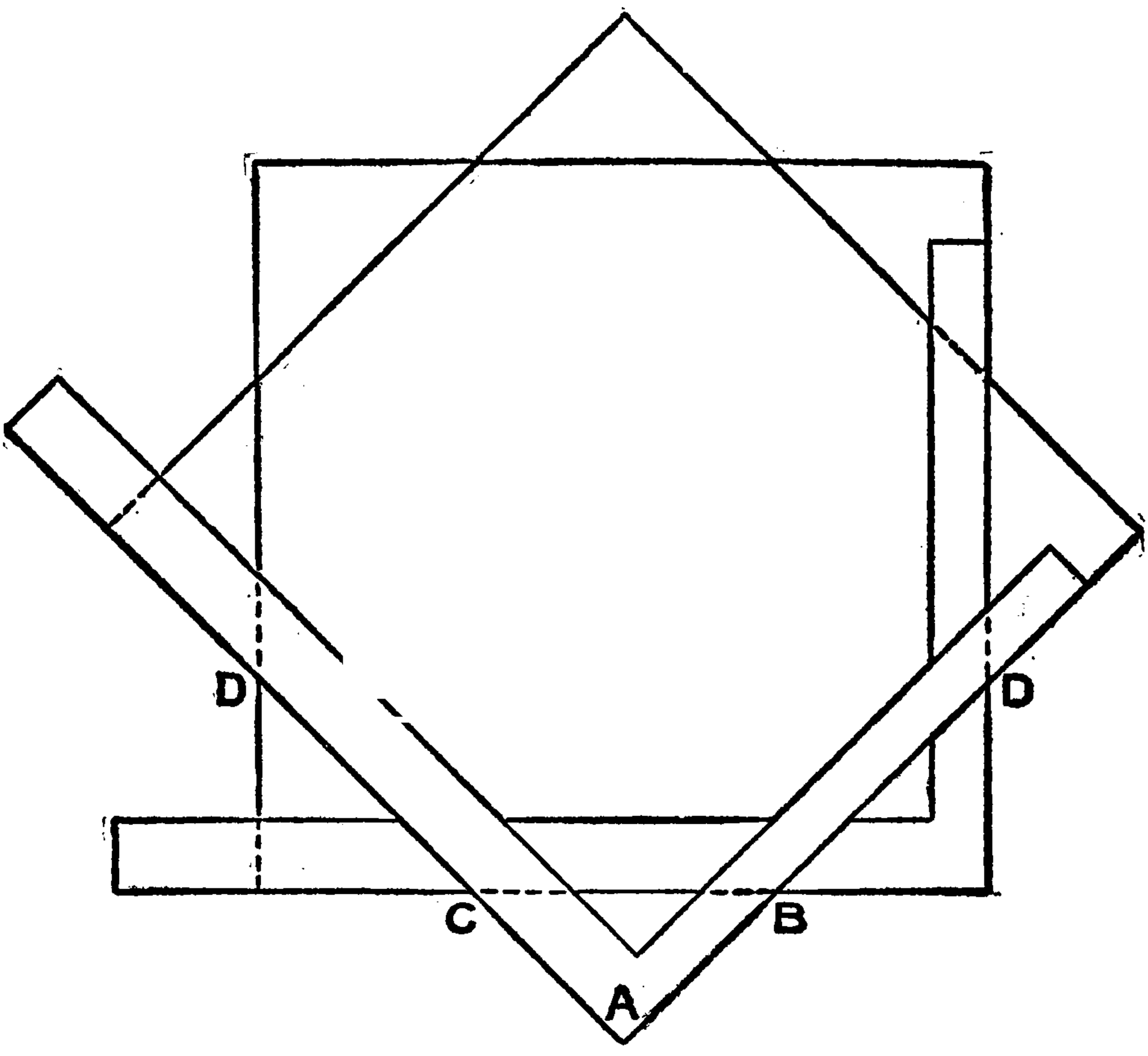

FIG. 174

1 and two-thirds feet, cut miter to suit this measurement, nail into corners of square box, and you have an octagon flask at once.

Another method of constructing an octagon is shown in Fig. 173.

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and apply as shown on a base line which forms a square around the figure.

Construction of a Pentagon or Five-sided Figure.—There are several methods of forming this figure, but we prefer the following: On a given line let A B, Fig. 176, be the length of one side;

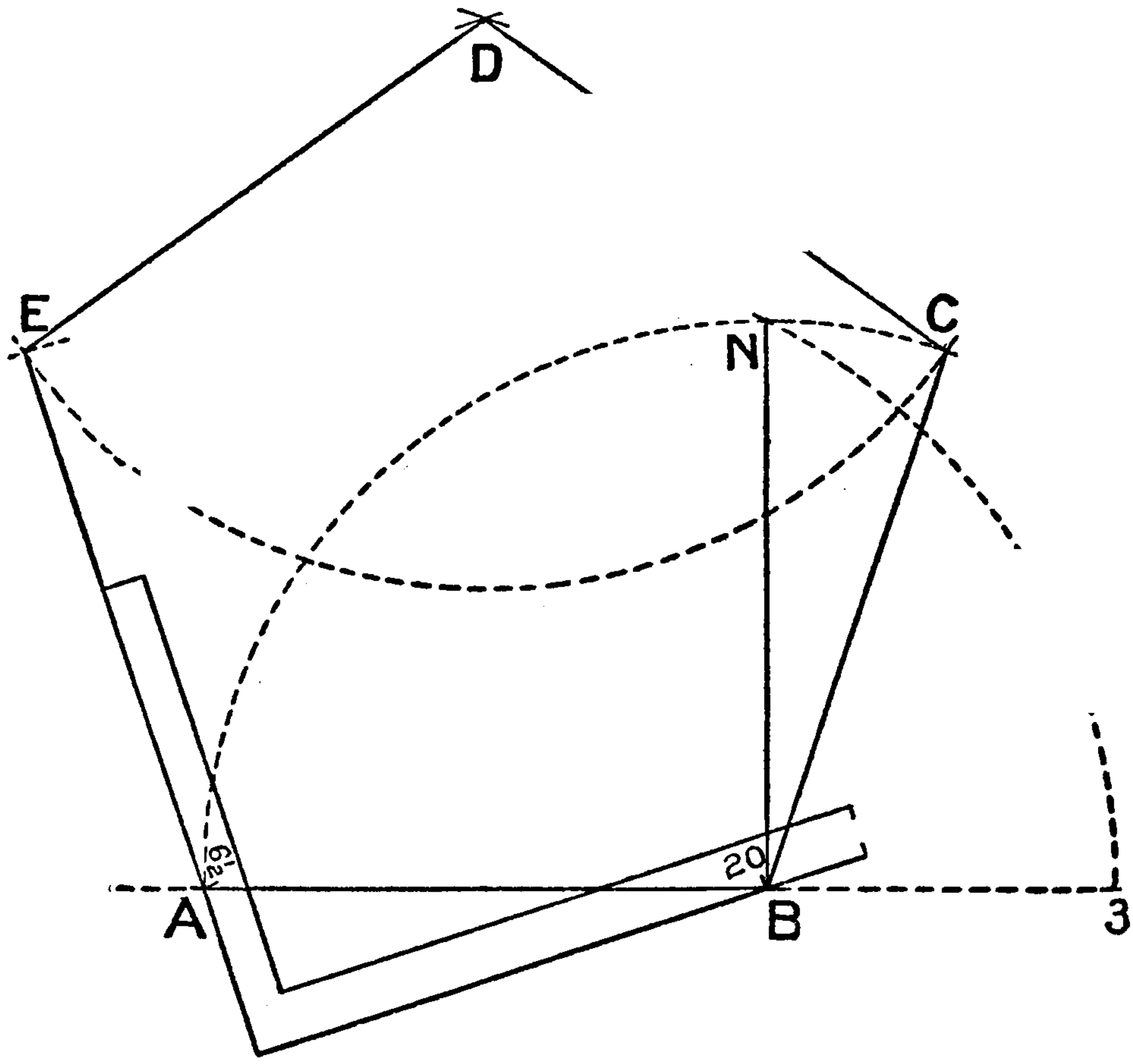

FIG. 176

divide this into two equal parts, marking it as at 2. From B square up a line, and make B N equal to A B, then with 2 as a center and 2N as radius, describe the arc, cutting the line A B at 3. Now take A3 for radius, and from A and B as centers

make the intersections at D; then from D, with a radius equal to A B, describe an arc as shown; then using A and B for centers, intersect the arc in E and C; connect these pionts together with straight lines, and the pentagon is complete.

This is a scientific way of forming this figure, but it may be obtained much easier by the square.

It may be necessary to explain that in regular equal-sided polygons the angles are equal, so any side of a regular polygon may be used for a base line. Let this fact be remembered, as it is important the student should keep it in mind when dealing with any problem connected with polygons, where the steel square is used: By careful examination of Fig. 176 it will be seen that the outer edge of the tongue of the square is in line with one side, A E, of the pentagon, measuring down below the base line, A B, six and one-half inches; then the 20 inch mark on the outer edge of the square will also touch the base line, A B, This position of the square then gives the exact inclination of the side of the pentagon with the base. Now if we reverse the square and place the $6\frac{1}{2}$ inch mark at B, and the 20 inch mark on the line A B, we give three sides of the figure. Now make the distance from A to E the same as A B, and we have the length of that side. Perform the same operation with B C. Then using A E and B C as base lines, we can form the complete figure. This shows how any pentagon having equal sides can be formed with the square.

We wish to recall again that $6\frac{1}{2}$ inches on the

tongue and 20 inches on the blade give the proper angle for forming pentagons.

To Obtain a Heptagon.—Fig. 177 shows a heptagon, or seven-sided figure, and the manner

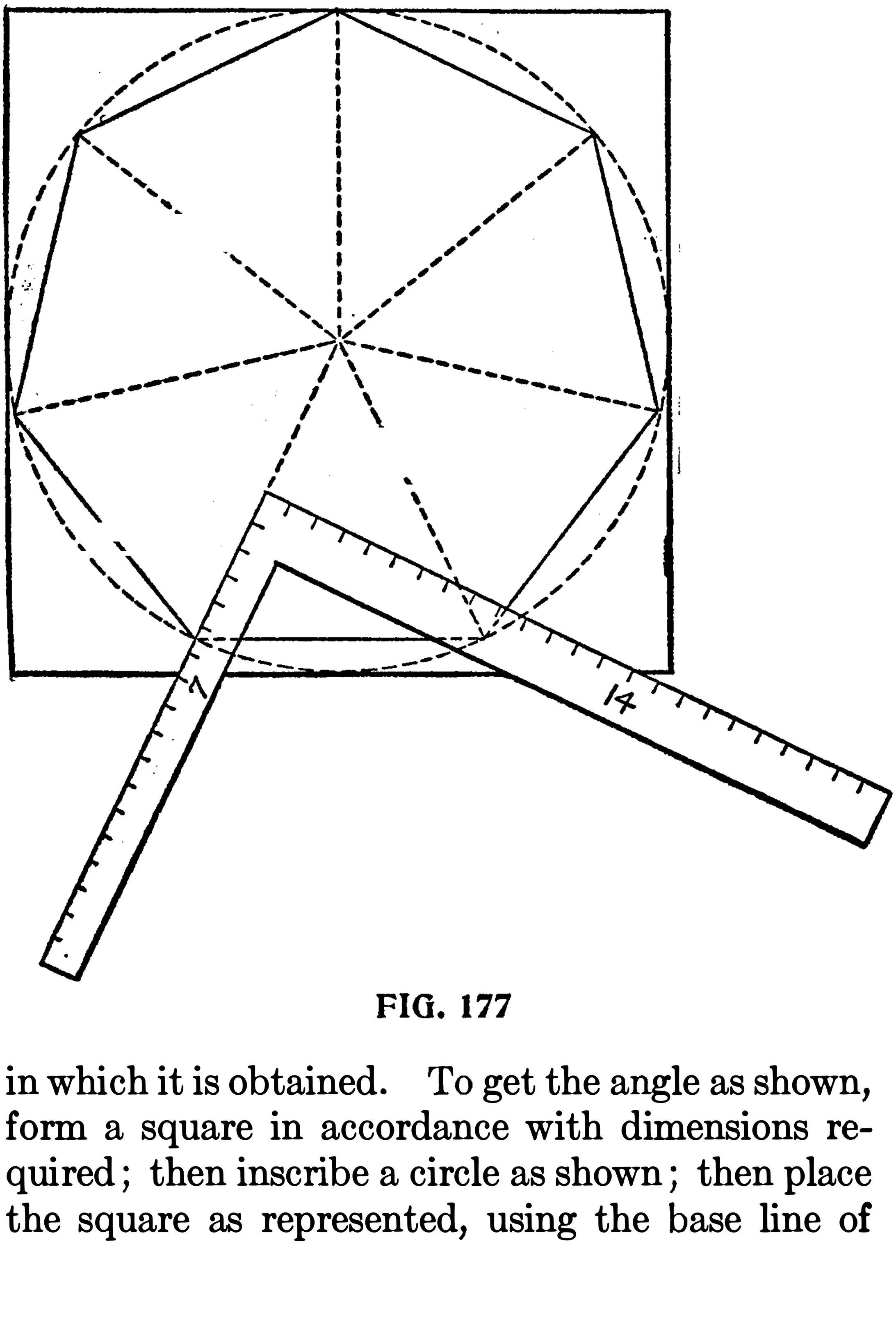

FIG. 177

in which it is obtained. To get the angle as shown, form a square in accordance with dimensions required; then inscribe a circle as shown; then place the square as represented, using the base line of

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the outside figure having the tongue running in a line with the center, keeping the 7 inch mark on the base line; then on the blade the 14 inch mark will be over the base line. Hence, 7 inches on the tongue and 14 inches on the blade gives the figures for finding the lines for a heptagon.

To Lay Off an Octagon in a Square.—In Fig. 178, measure off the side of the square on its diag-

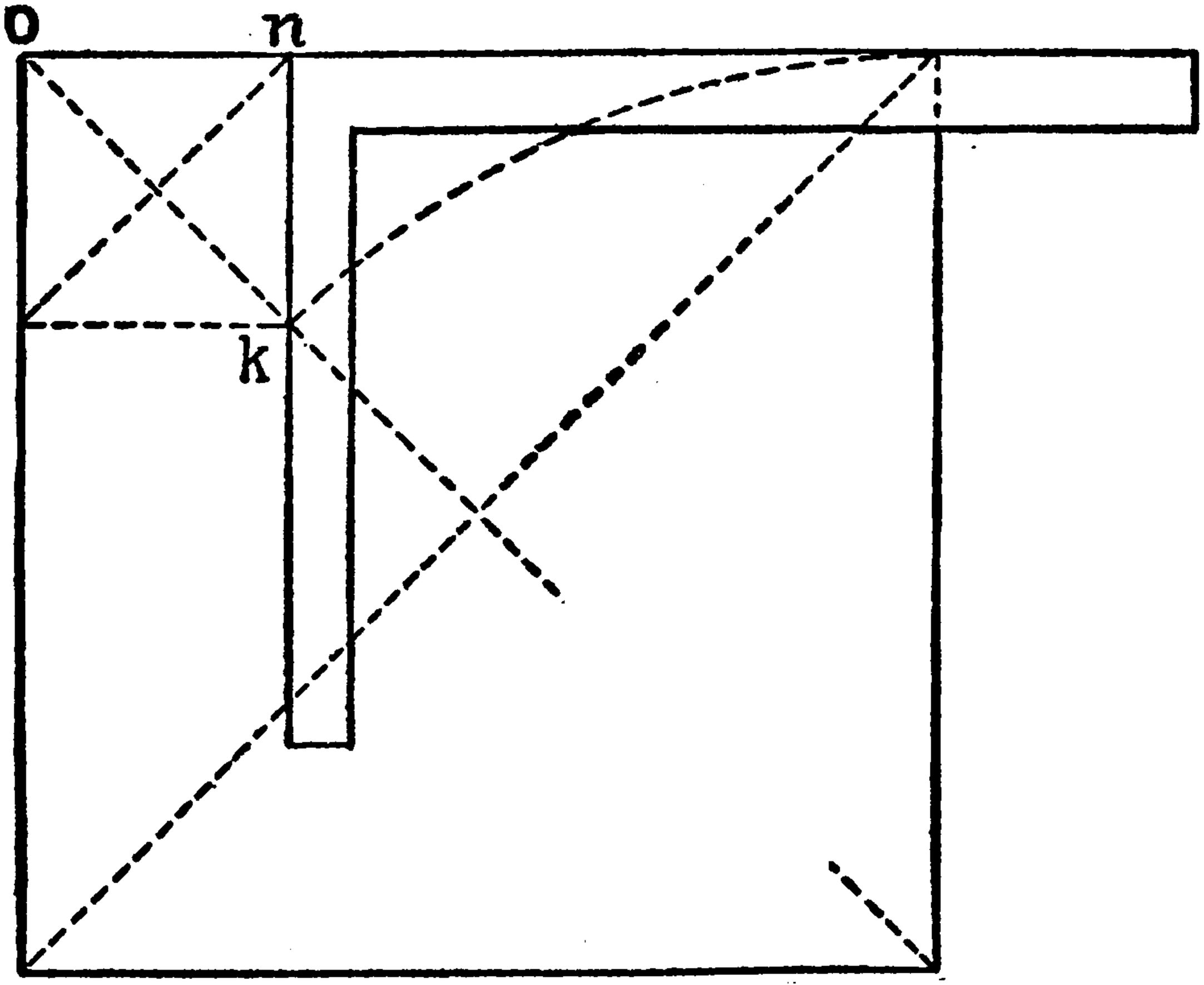

FIG. 178

onal k. Square from a side to the point thus found on the diagonal, and n o is the distance to be gauged from each corner, to mark the corners of the octagon.

When the Side of the Octagon is Given to Find the Square Width.—Suppose the side of the octagon

is to be 16 feet; take half this or 96 inches for the square, 16 inches on both tongue and blade taken 6 times, giving 11 feet $3\frac{3}{4}$ inches, which, being doubled and added to the side of the octagon, gives the square width.

To Obtain Correct Shape of a Veneer.—Fig. 179 shows a method of obtaining the correct shape of a

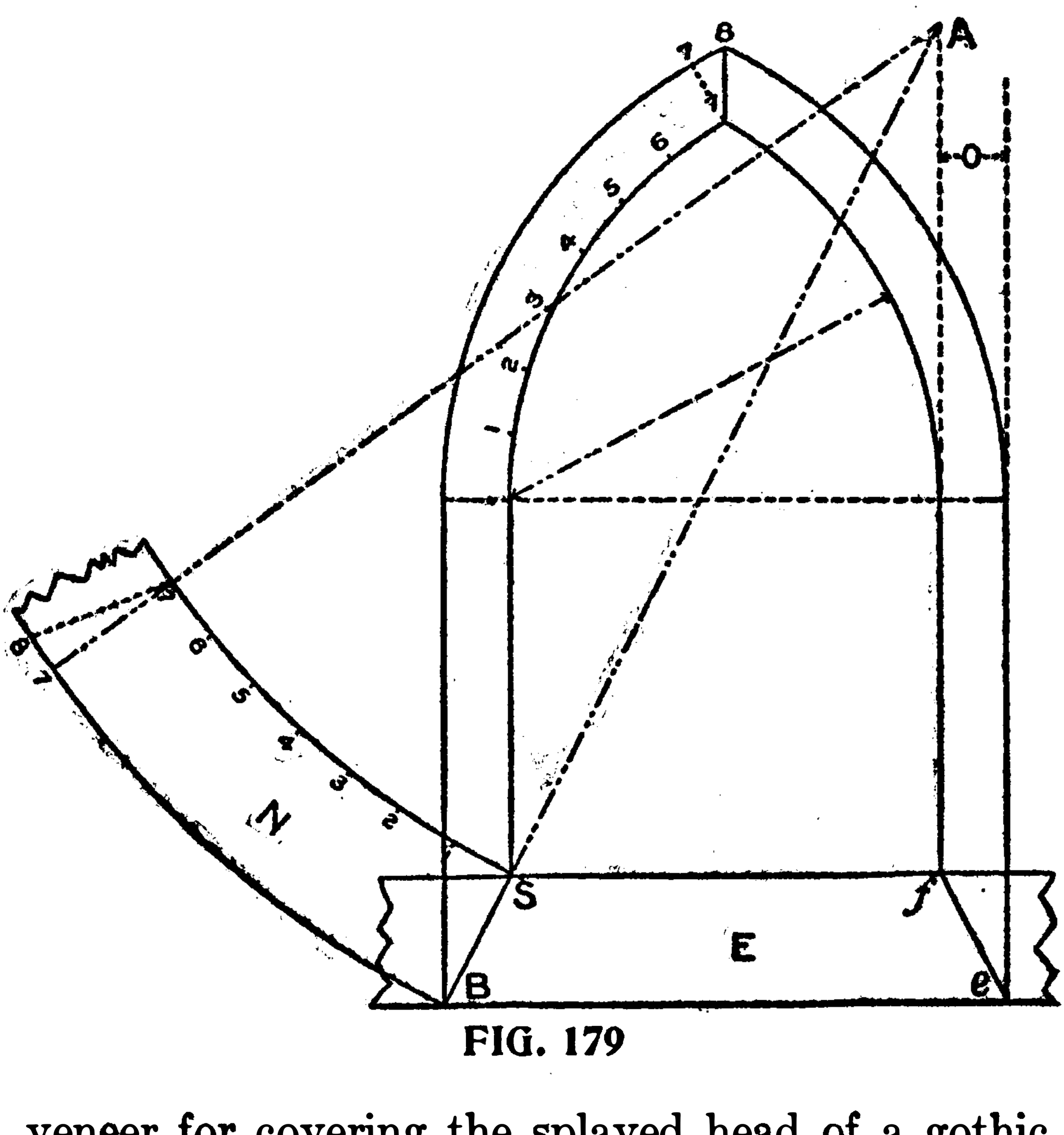

FIG. 179

veneer for covering the splayed head of a gothic jamb. E shows the horizontal sill of the splay, fA the line of the inside of jamb, o the difference between front and back edges of jamb, BA the

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instance, if a piece of stick 2¾ inches square is to go into the construction, the draughtsman finds the 9¼-inch mark on the blade, that is 2¾ inches back from the 12-inch mark, and measures square out to the rule. This distance is the reduced section of the stick. A straight mark, drawn on a table or a drawing board, serves as well as a rule.

Polygons and Miters

In the following paragraphs we present still further examples of the application of the steel square to the solution of problems that are to a greater or less extent of a mathematical nature, some of which are ordinarily solved only by the methods of geometry or trigonometry.

Polygons Inscribed in Circles.—In the following table, set the bevel to the pair of numbers under the polygon to be inscribed.

No. of sides	3	4	5		6		7	8	9	10	11	12
Radius	56	70	74	Side equal to radius			60	98	22	89	80	85
Side	97	99	87				52	75	15	55	45	44

If we require the radius of a circle which will circumscribe an octagon 8 inches on a side, we refer to column 8, take 98 parts on the blade and 75 on tongue, and tighten the bevel. As the side of a hexagon equals the radius of its circle, the side of an octagon must be less than the radius; hence we shift to 8 inches, that end of the bevel blade which gives the lesser number, in this case, on the tongue of the square, as the 75 parts to which the bevel was set are less than the 98. The required radius is then indicated on the blade.

We will now explain the figures used in stepping round a circle forming inscribed polygons from three to twelve sides: Set bevel or fence to 12 on blade, and the number opposite each poly-

gon on tongue; move to diameter of circle; answer of the side of polygon on tongue.

NAMES.	NO. OF SIDES.	GAUGE POINTS.
Triangle	3	10.40
Square.....	4	8.49
Pentagon	5	7.05
Hexagon	6	6.00
Heptagon	7	5.21
Octagon	8	4.60
Nonagon	9	4.11
Decagon.....	10	3.71
Undecagon	11	3.39
Dodecagon	12	3.11

To Divide a Circle into a Given Number of Parts, multiply the corresponding number in column one and the product is the chord to lay off on the circumference. **The side of the polygon being known, to find the radius of a circle that will circumscribe:** Multiply the given side by the corresponding number opposite of polygon in column two.

No. of Sides	Names of Polygons	Angle	Angle of Polygon	Column 1	Column 2
3	Triangle	120	60	1.732	.5773
4	Square.	90	90	1.414	.7071
5	Pentagon ...	72	108	1.175	.8510
6	Hexagon	60	120	Radius	Side
7	Heptagon ...	$51\frac{3}{7}$	$128\frac{4}{7}$	.8677	1.1520
8	Octagon .	45	135	.7653	1.3071
9	Nonagon ..	40	140	.6840	1.4863
10	Decagon.	36	144	.6180	1.6181
11	Undecagon	$32\frac{8}{11}$	$147\frac{3}{11}$	.5634	1.7754
12	Dodecagon ..	30	150	.5176	1.9323

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180 by the number of the sides in the polygon and the quotient will represent the angle in degrees to use on the steel square to obtain the miter. The blade giving the cut. The figures used on the blade also give the length of the sides of the polygon when the inscribed diameter is one foot. These figures are also used for cuts in roof work.

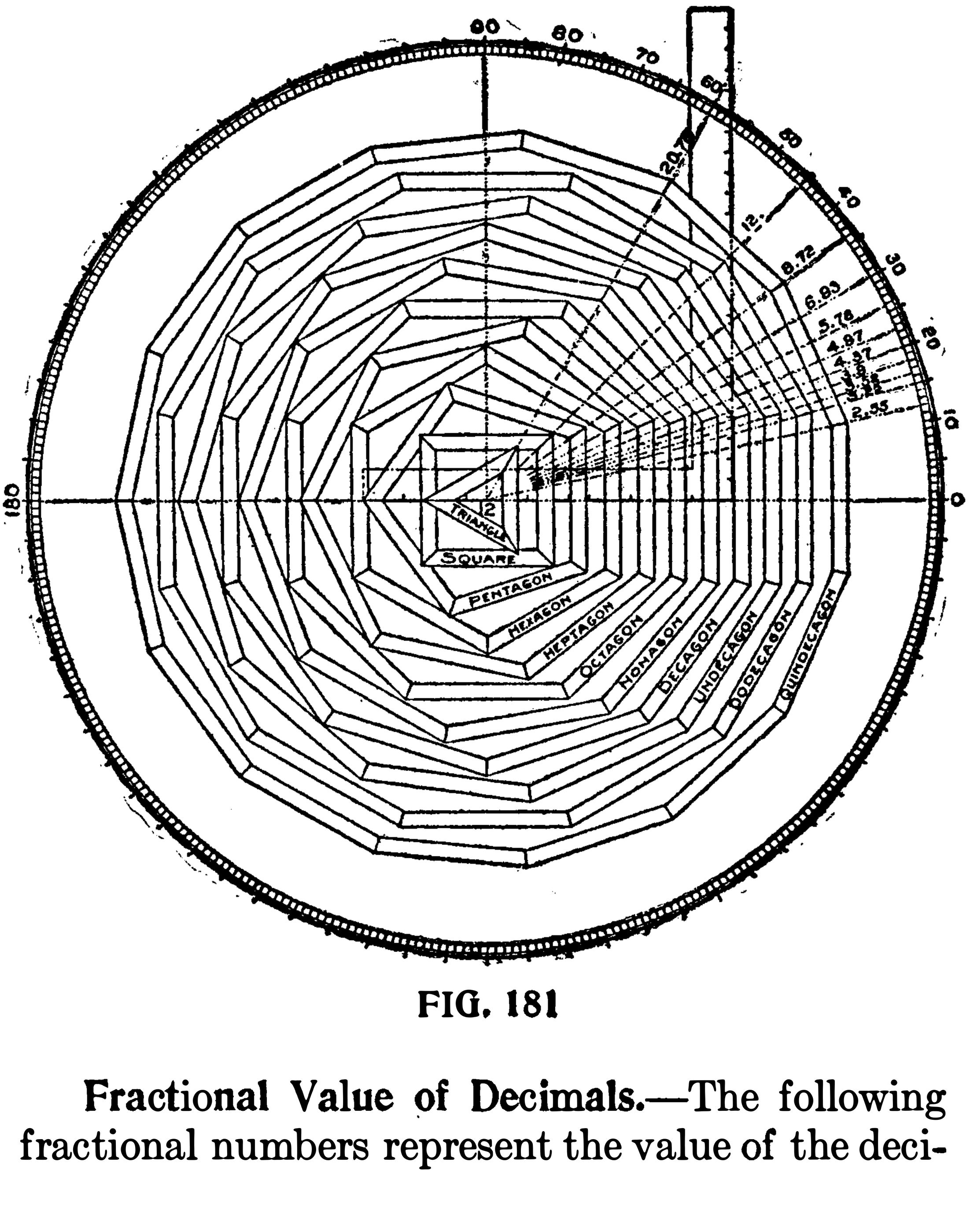

FIG. 181

Fractional Value of Decimals.—The following fractional numbers represent the value of the deci-

mal numbers shown on the degree lines and are the figures to use on the blade as follows: triangle, 20 19-24; square, 12; pentagon, 8 17-24; hexagon, 6 11-12; heptagon, 5 19-24; octagon, 4 23-24; nonagon, $4\frac{3}{8}$; decagon, 3 11-12; undecagon, $3\frac{1}{2}$; dudecagon, 3 5-24; quindecagon, 2 13-24.

These fractional numbers are to the 1-24 part of an inch and are about as near as can be had on the steel square, none of them varying over .02 of an inch. Polygons are known by the number of their sides as per the above names given in their order up to the twelve sided figures, after that, with the exception of fifteen which is called quindecagon, are known as polygons of so many sides.

In some of the encyclopedias the triangle and square are not classed with the polygons, but we see no reason why they should not be, since the rule that applies to other sided figures applies to them also.

The subject of polygons is not as well understood as it should be. It is quite a common thing to call most any kind of a corner aside from the right angle, an octagon corner, due no doubt to the fact of their little demand in practical work, for, aside from the octagon, they are but little used. However, it is well to know them, and to know one is to know them all.

Though many of the illustrations that we have given may never come up in actual practice, they show that when the principles are once undersdood the mechanic will know how to proceed

to apply the square to solve anything pertaining to angles in his line of work. However, we have a few more illustrations that we wish to present before passing them by.

In Fig. 182 is shown an example in line work.

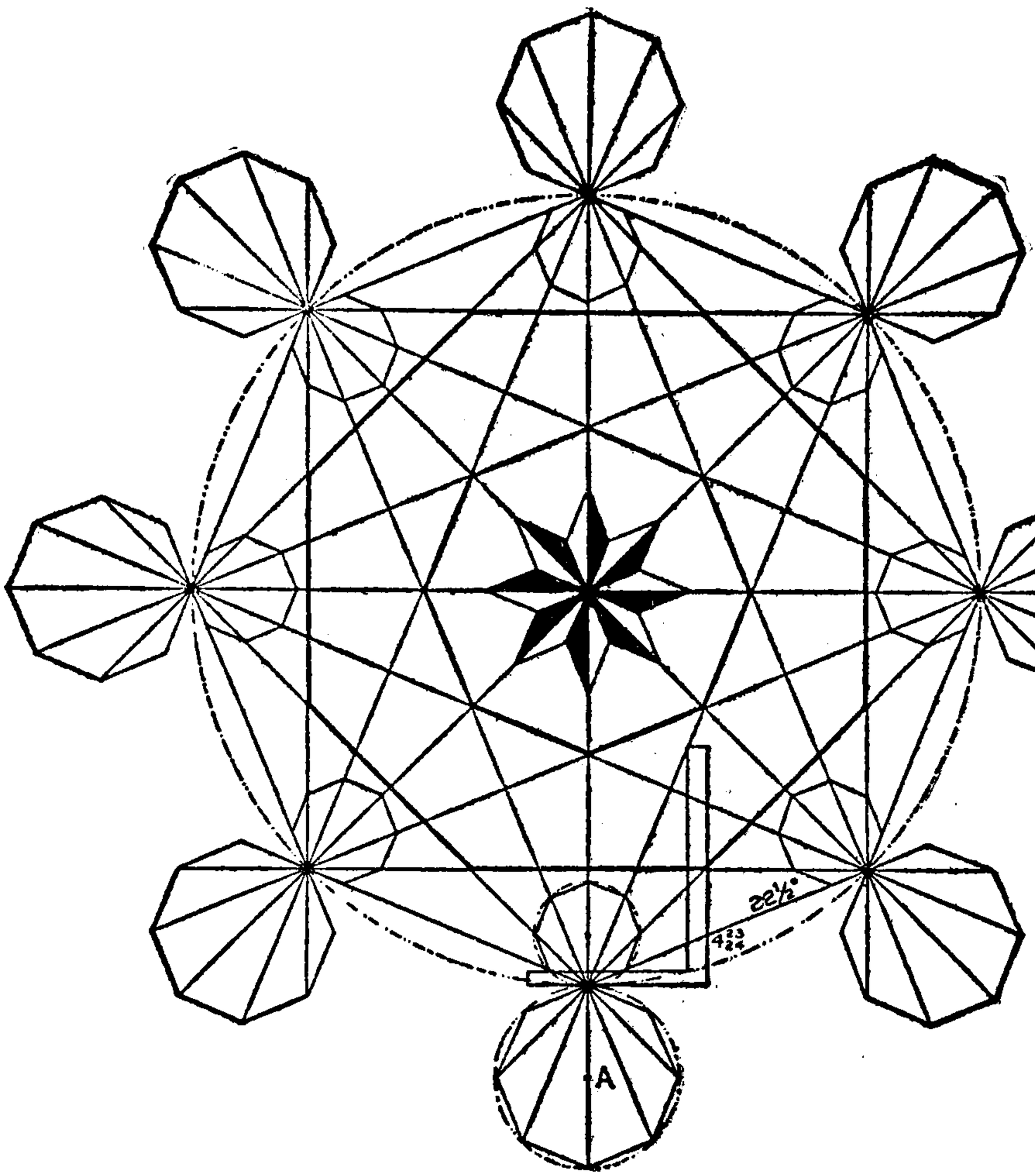

FIG. 182

The figures to use on square are those for the octagon miter and consequently the whole figure runs to the octagon. The eight lines radiating from 12 on the tongue are 22½ degrees apart, the first one intersecting the blade at 4.97, or

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drawn and the interior octagons will be formed as shown.

Those on the outer edge are formed by letting the cross lines extend beyond the large circle and from the center line as at A describe a circle cut-

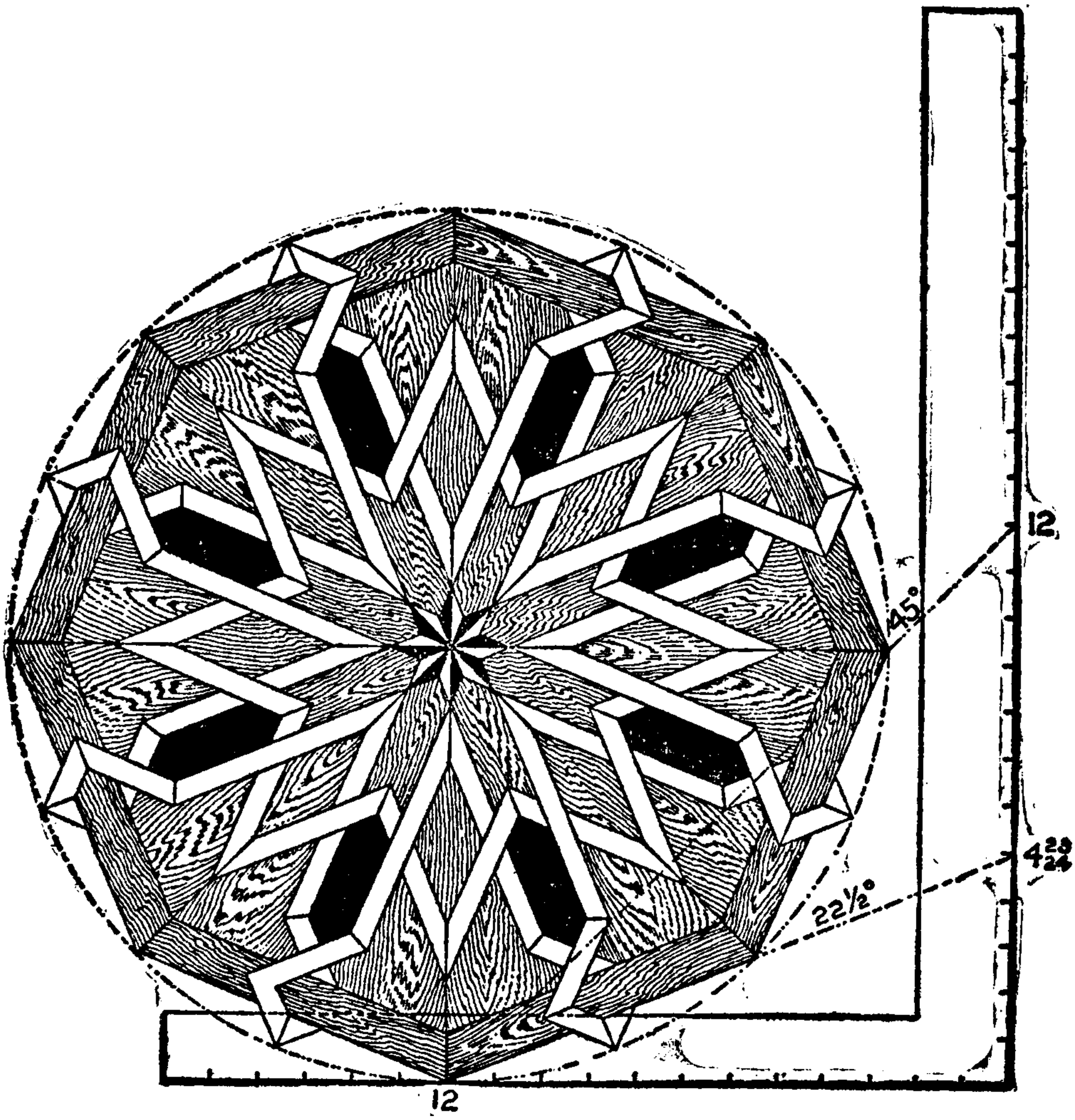

FIG. 184

ting these lines and connecting up the ends will form the octagon as shown.

In Figs. 183 and 184 are shown patterns suitable for parquet or inlaid work. All of the miters

contained in these designs can be had on the 22½ and 45-degree lines and the figures shown on the square when applied will give all of the angles as well as the miters contained in these illustrations.

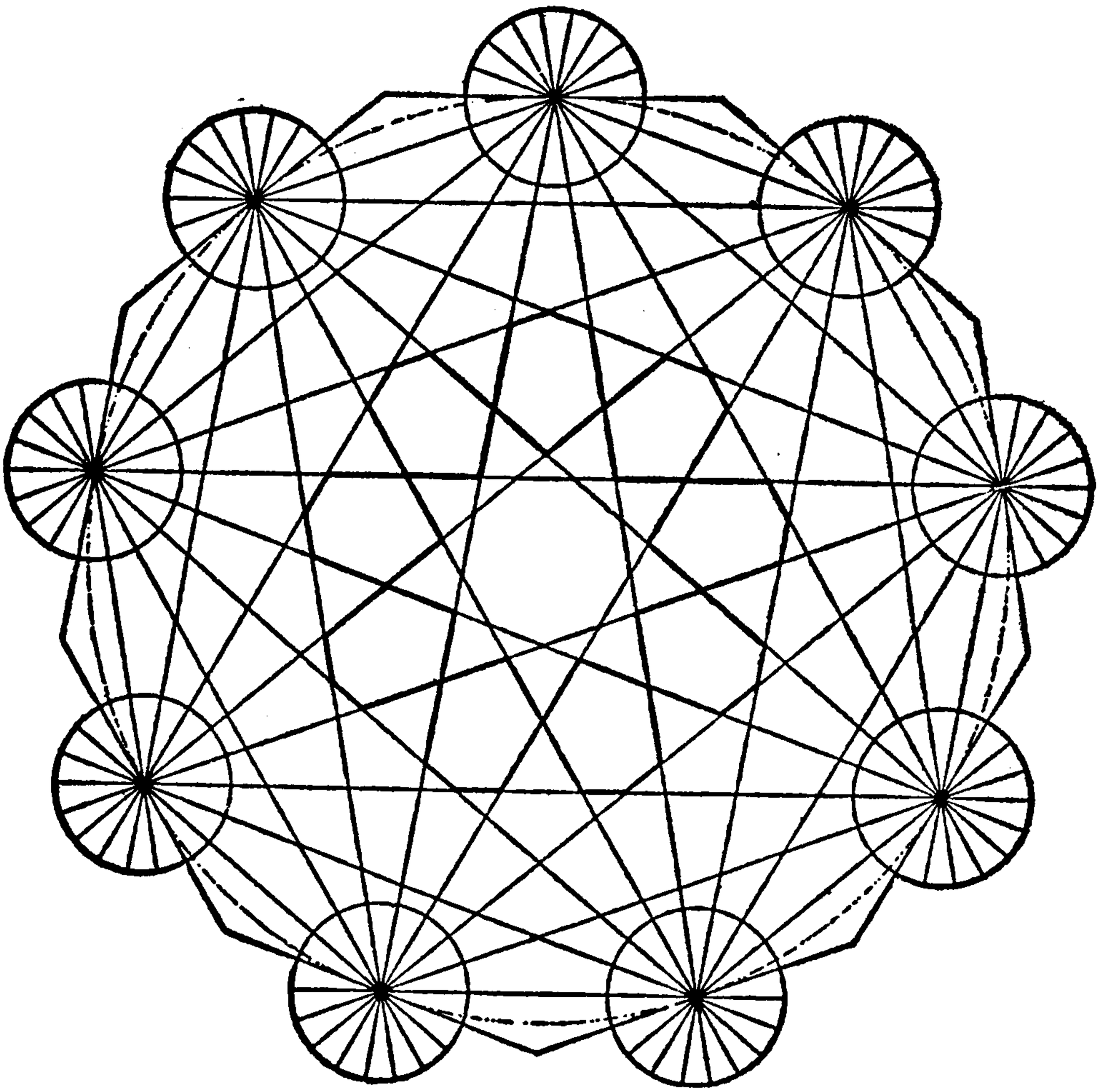

FIG. 185

In Fig. 185 is shown an example in line work for the nonagon or nine-sided polygon. We have not shown the square in connection with this illustration, but the figures to use are for the 20-

degree, because 9 is contained in 180 twenty times. The small circles are divided into eighteen parts because 20 is contained into 360 degrees eighteen times. A further explanation of this illustration would be useless, as it shows for itself.

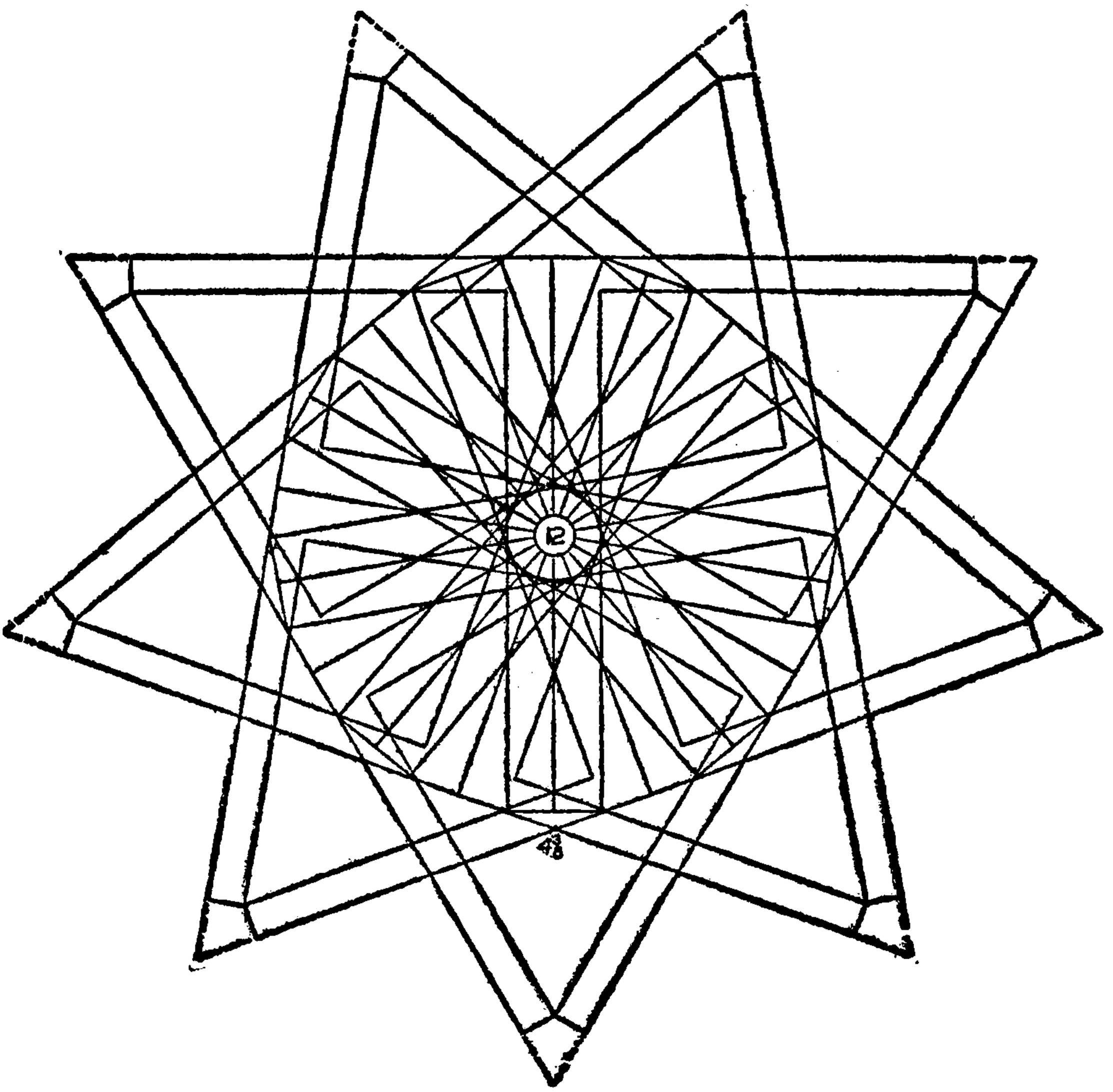

FIG. 186

In Fig. 186 is shown a very pretty design made with eighteen squares. In this the center is at 12 on the blade and the intersection at $4\frac{3}{8}$ on the tongues, which is at the 20-degree line and represents the nonagon as will be seen by the forma-

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The intersections rest at 10 degrees apart on a circle with a diameter equal the distance from 12 to 12 on the tongues of the opposite squares, and by connecting the intersections forms a polygon of eighteen sides. This rule applies to any other polygon, but is not a practical way of solving problems of this kind, because there are simpler ways of arriving at the same result.

With this we close with polygonal figures, as we think we have given enough to show that all work pertaining in any way to angles may be readily obtained by the use of the common steel square.

To Measure Inaccessible Distances by Aid of the Square.—The following is from an article written by Mr. A. W. Woods, of Lincoln, Neb., and is only modified so as to place the subject before our readers in its simplest form.

Every mechanic knows that a triangle whose sides measure 6, 8 and 10 forms a true right angle and is the method commonly used in squaring foundations. But how many ever stopped to think what other figures on the square will give the same result?

By referring to trigonometry we find only three places, using 12 inches on the tongue as a basis and measuring to the inches on the blade that do not end in fractions of one inch on the hypothenuse side. They are as follows: 12 to 5 equals 13, 12 to 9 equals 15, and 12 to 16 equals 20.

Now, as we usually use a 10-foot pole to square up a foundation, we find that all of the

above contain lengths greater than our pole, so we must take their proportions. The first con-

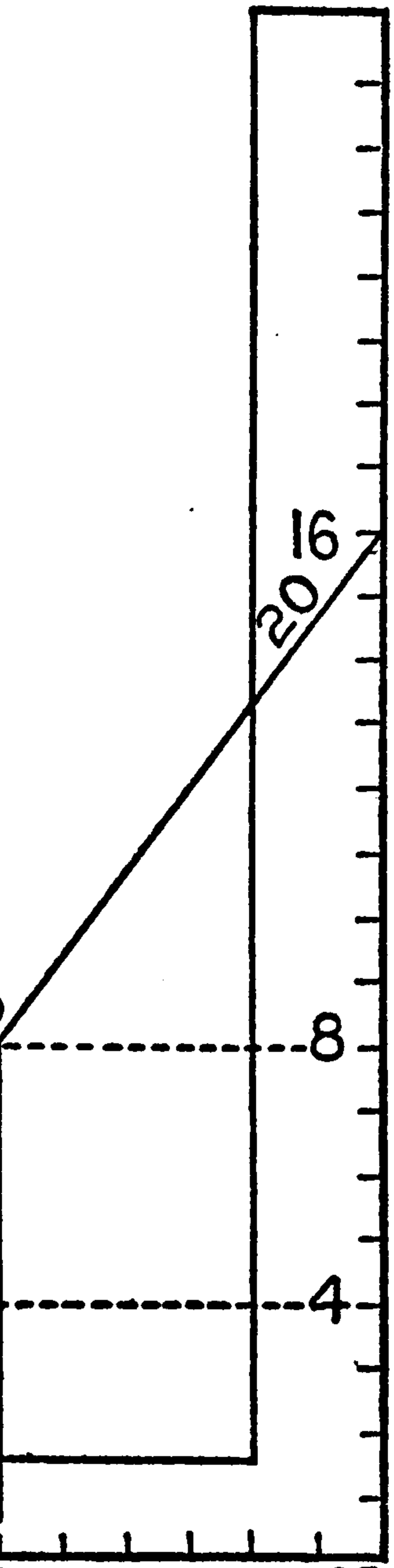

FIG. 188

tain numbers not divisible without fractions, consequently we will pass on to the next. We

find that three is the only number that will equally divide all the numbers with quotients, as follows: 4, 3 and 5, but these are too small to obtain the best results. Now let us examine 12, 16, and 20. They are even numbers, and are divisible by 2 and 4, Fig. 188. If we take half their dimensions we have 6, 8, 10.

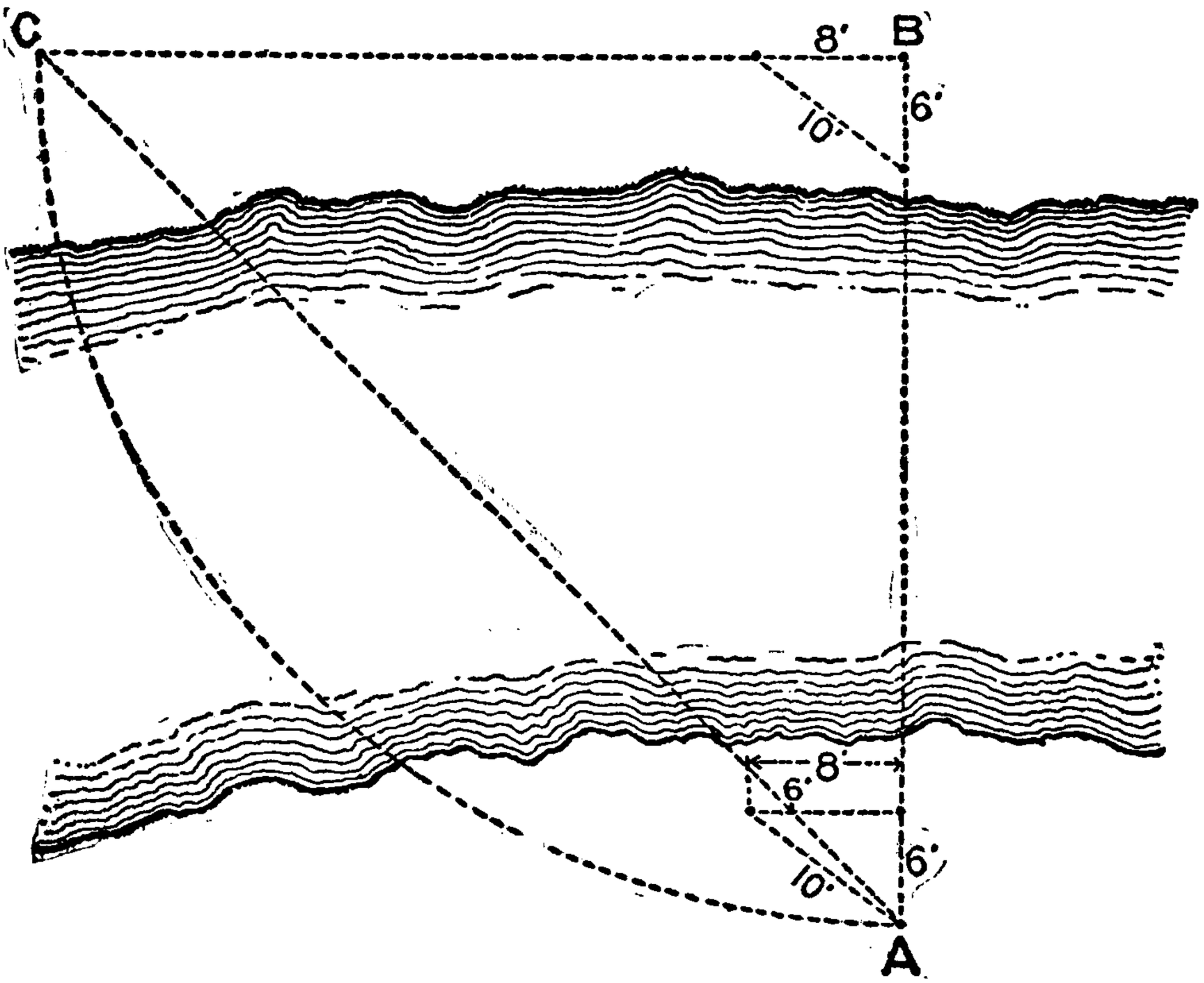

FIG. 189

These being convenient lengths and easily remembered, custom has settled on these figures.

There are other places that 6, 8, and 10 can be used to advantage.

To Find the Distance Across a Body of Water.—Suppose for some reason we want to know the distance across a body of water. We cannot wade

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in Fig. 191. Here we have a 6-inch pipe intersecting a two-thirds pitch. A line from 12 to 16 on the square represents the pitch. Now with 12 as center and with radius equal to one-half of the diameter of the pipe draw a circle and square up from the tongue to the pitch, as shown at B C.

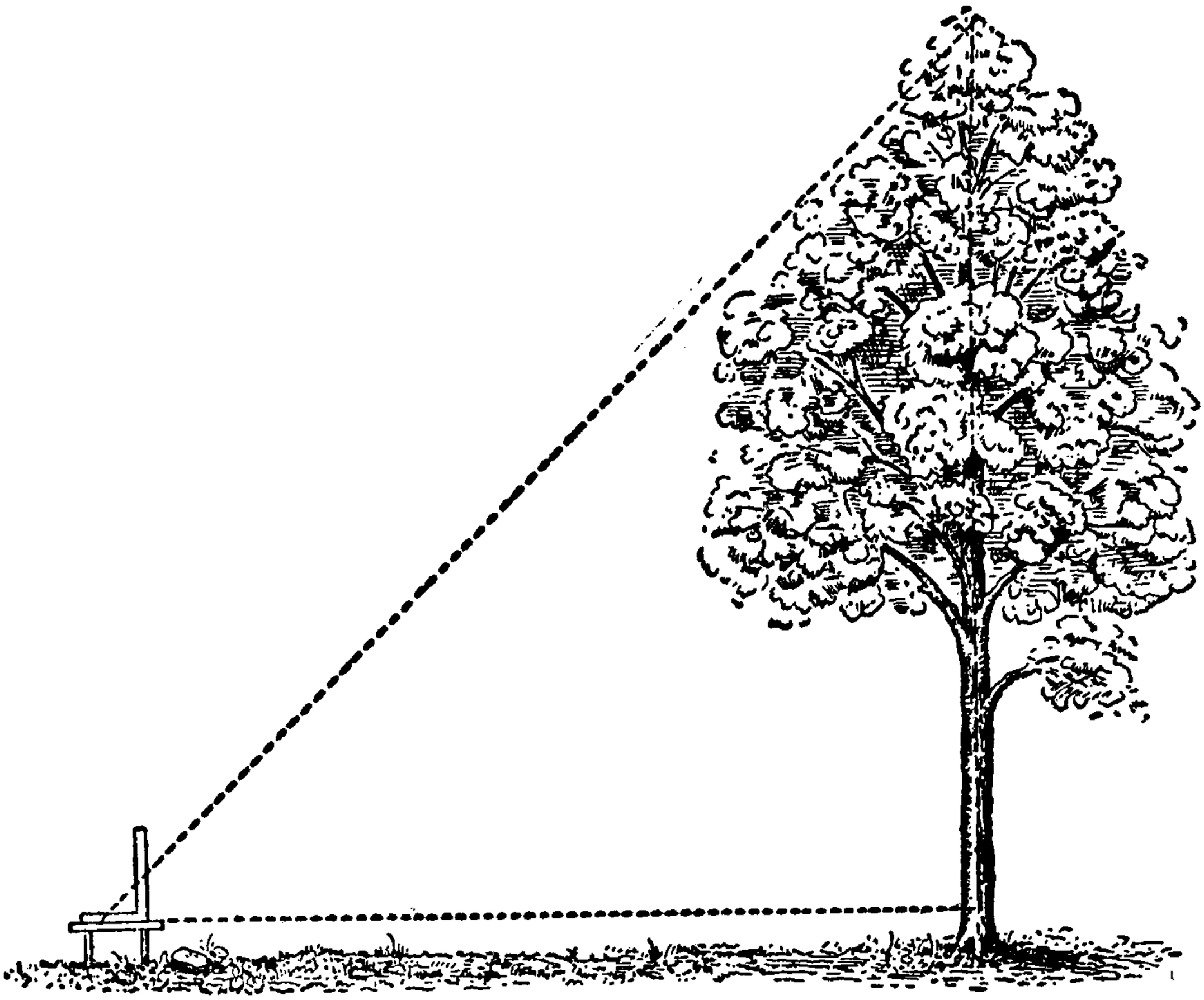

FIG. 190

Then A B represents one-half of the short diameter, and A C one-half of the long diameter. Now to make our illustration more clear we will transfer these lengths to a line at right angles with the tongue, crossing at 12.

There are several ways of finding the corresponding opening. Probably as good a method as any

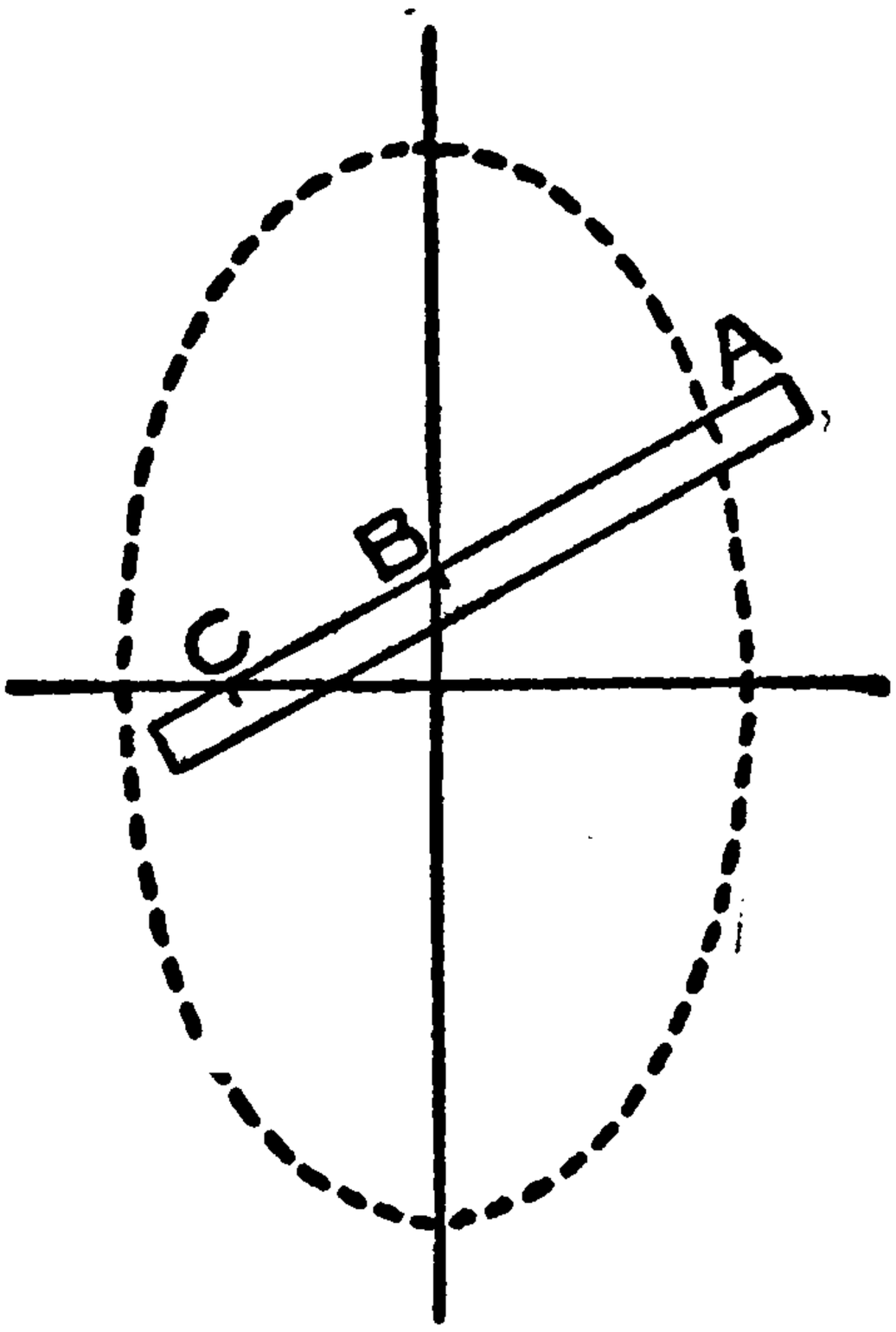

FIG. 192

FIG. 191

is that shown in Fig. 192, which is as follows: Take a straight-edge, and on it space off A, B″, C″, as shown in Fig. 191. Now draw a line equal to the long diameter, C D, and bisect it at right angles, and to these lines apply the straight-edge, as shown in Fig. 192. Always keeping B C on the lines and marking at A will describe the required opening. The steeper the pitch the longer will be the required opening. In Fig. 193 is shownthe same formula, but with the one-third pitch

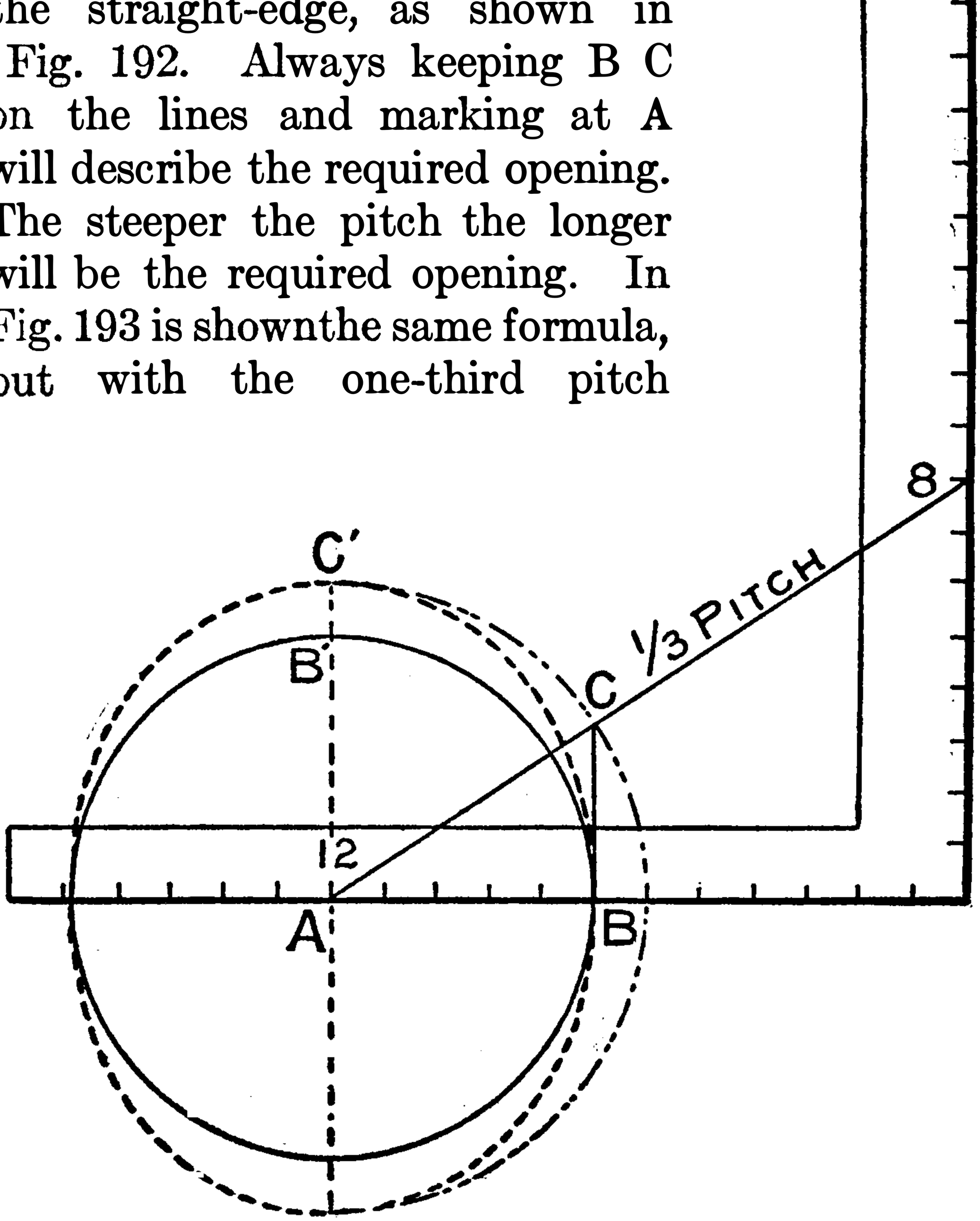

FIG. 193

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Pitches and Roof Framing

The young mechanic who attacks the problem of roof framing will find that it involves many features entirely distinct from those that confronted him in framing ordinary walls, floors, etc. If the steel square was found of great assistance in the latter, it will prove absolutely indispensable in laying out the timber and lumber for roofs.

Examples and Explanations on Roof Framing.—The following examples and explanations on roof framing are simple and easily understood, and cannot fail of being valuable to the young mechanic who aspires to become an expert roof framer.

Roof framing can be done in about as many different ways as there are mechanics. But undoubtedly the easiest, most rapid, and most practical is framing with the square. The following cuts will illustrate several applications of the square as applied to roof framing, and all who are interested in the subject can, by giving it careful study, be able to frame any ordinary roof the mechanic comes in contact with.

Pitches and Degrees.—Fig. 195 is an illustration that may well be given much study. It not only gives the most common pitches, but

also gives the degrees. Most carpenters know that half pitch is 45 degrees, yet few know third-pitch is nearly 34, and quarter-pitch about 27 degrees.

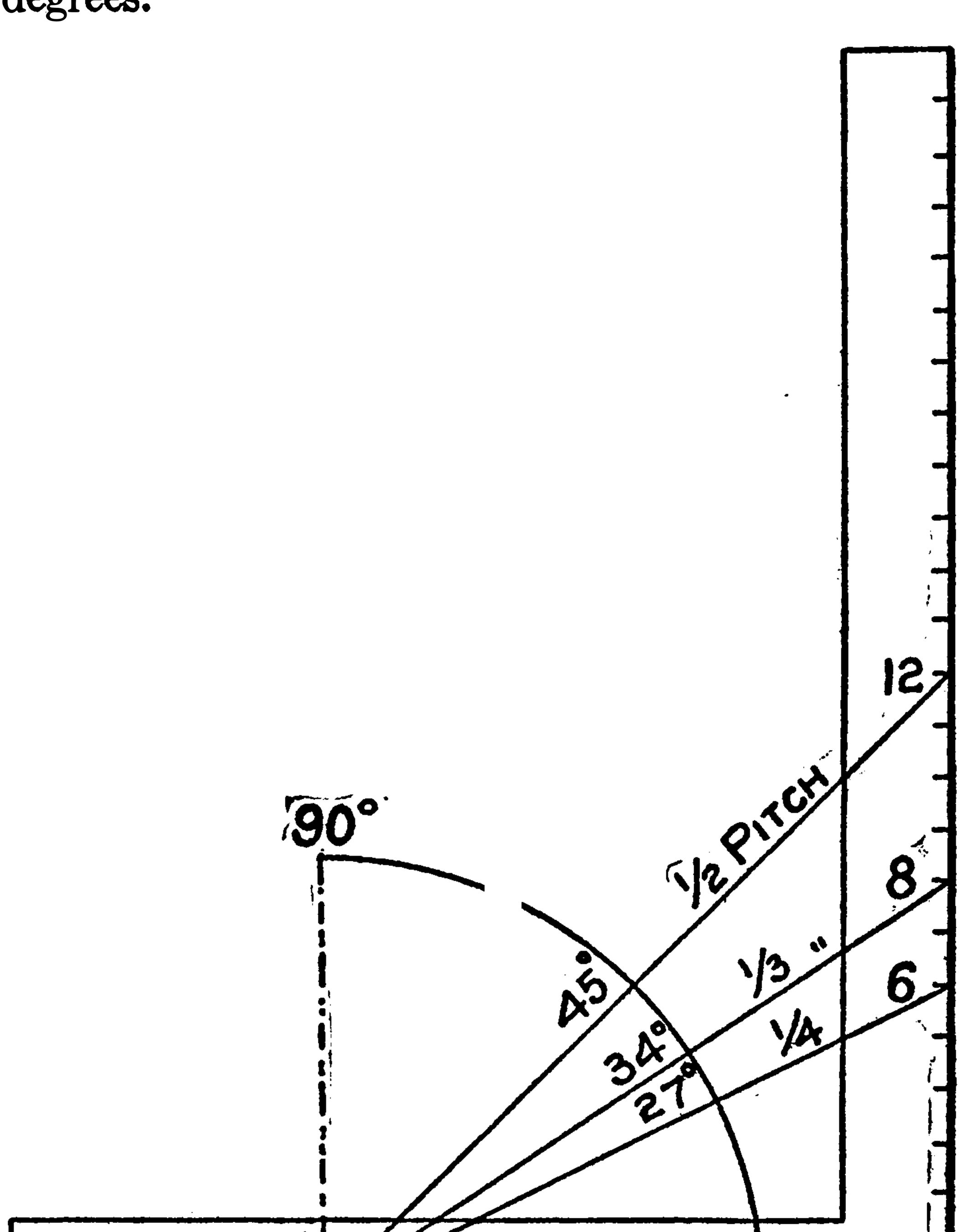

FIG. 195

A building 24 feet wide (as the rafters come to the center) has a 12-foot run and half-pitch, the

rise would also be 12 feet, and the length of the rafter would be 17 feet (the diagonal of 12). Length, cuts, etc., could all be figured from the one illustration.

Pitch Lines and Reversed Pitch.—In the illustration at Fig. 196 we show the pitch lines up to the full pitch, also the reversed pitch. That is,

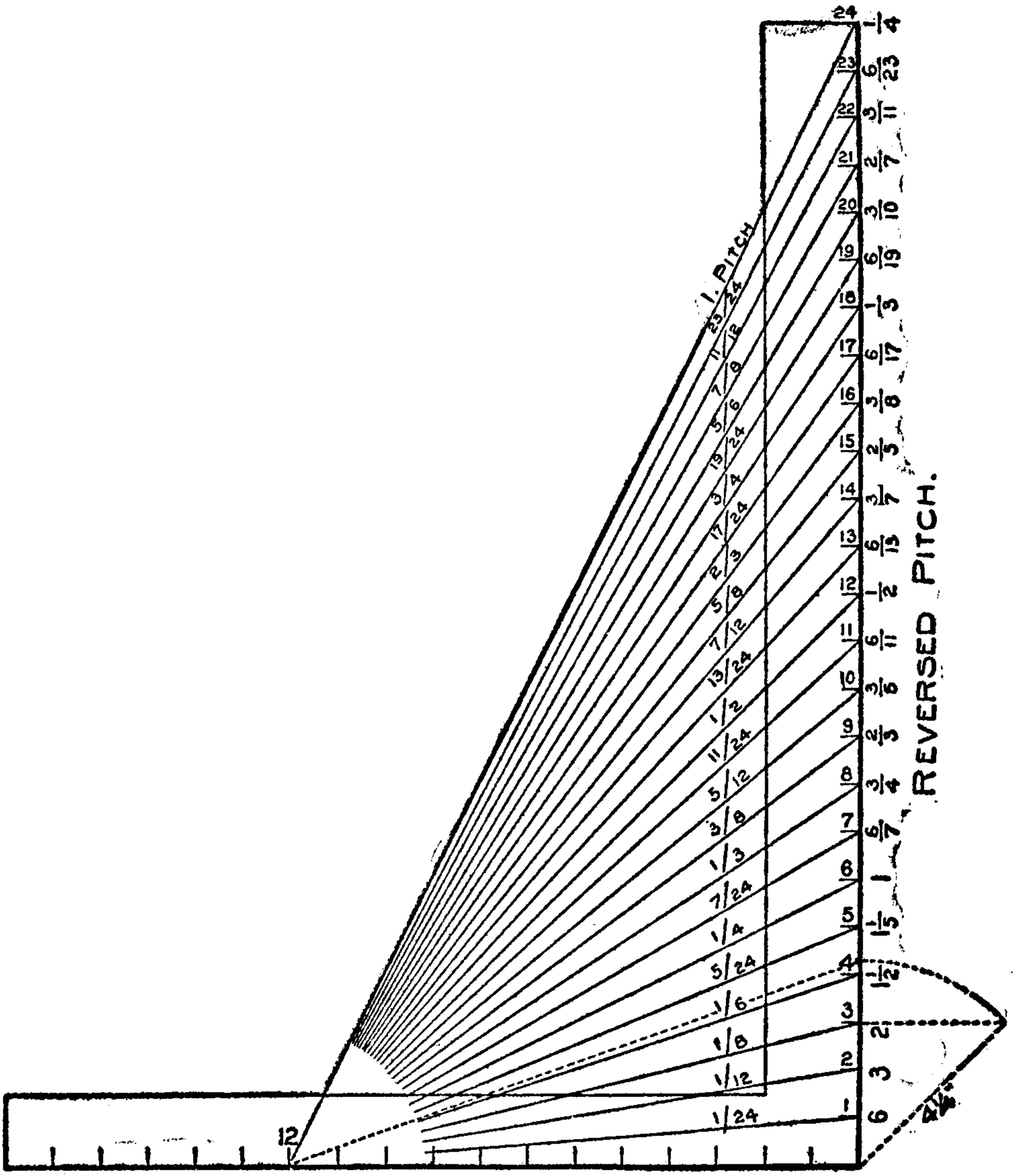

FIG. 196

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Steep Pitches.—**In Fig. 197** is shown how to apply the steel square for steep pitches. **In this**

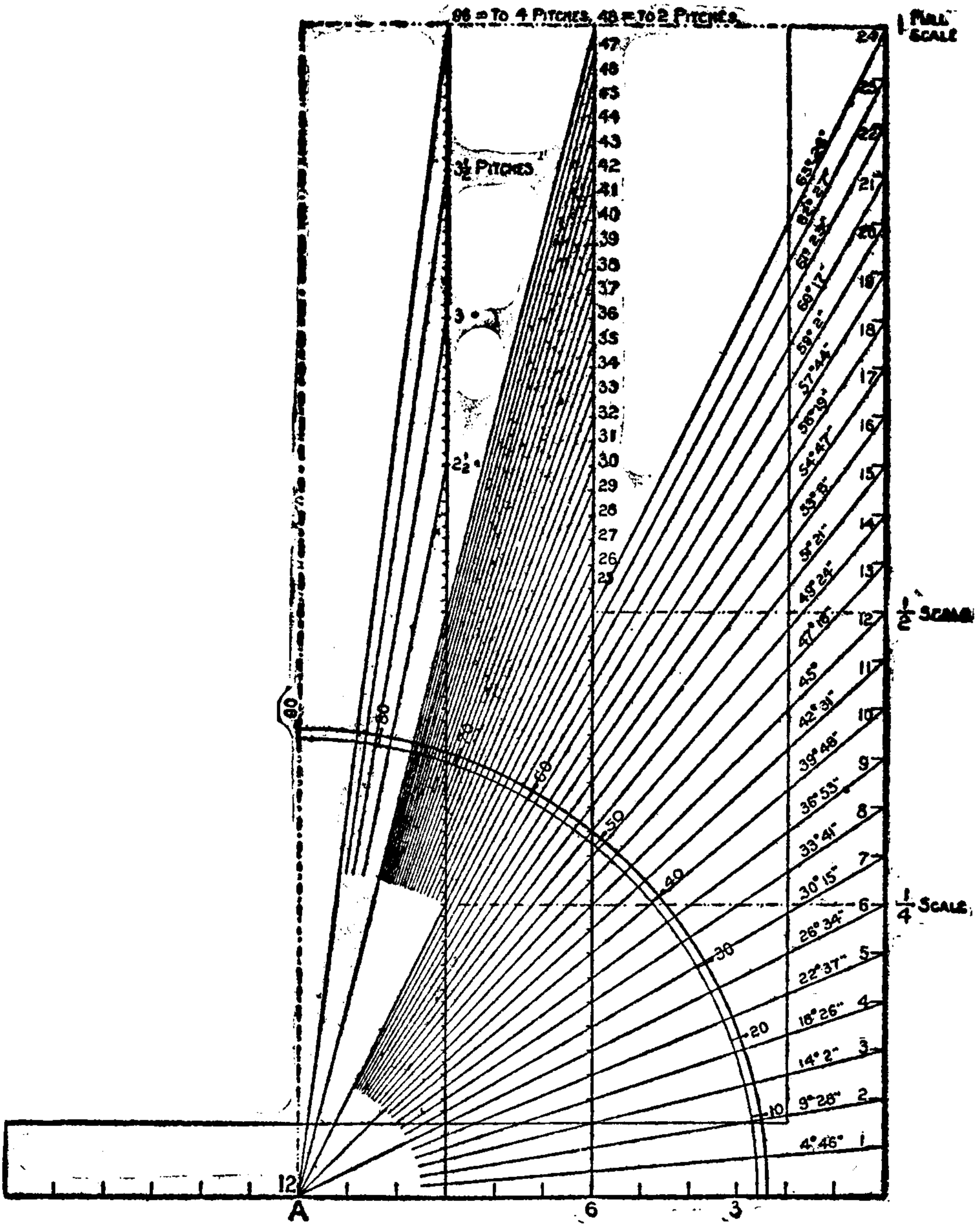

FIG. 197

illustration we show all of the pitch lines up to 96-inch rise to one foot in run, or four full pitches.

The pitch lines shown in connection with the steel square, represent the same up to the full pitch. Now leaving the pitch lines as they are and just imagine that we slide the square to the left until the 6-inch mark on the tongue rests at the starting point A, and it will be seen that the scale has been reduced one-half; in other words, the pitch lines would intersect the blade at the ½-inch marks, thereby permitting of a 48-inch rise to a one-foot run. The 48 being double 24 (the span) is therefore equal to two full pitches. If it is necessary for a still further reduction, just slide the square again to the left until the 3-inch mark on the tongue rests at the starting point. The pitch lines will then intersect the ¼-inch marks on the blade and permitting of 96 inches rise to one foot in run, or four full pitches. These, of course, are unusual, but the rule that applies to the common pitches, that is, those most generally used, necessarily applies to these.

For the corresponding hip or valley for the pitch lines above the full pitch, use 8½ on the tongue for the ½ scale and 4¼ for the ¼ scale. It will be seen that by the reduction in the scale, taken on the tongue of the square, permits of many pitch lines on the blade, thereby increasing the rise to any desired height.

In this illustration we give the degree and minutes of pitch for the common rafter up to the full pitch. To find the same for the reversed pitch lines, it is only necessary to subtract the degrees here given from 90 degrees. Thus—to

find the degrees for the full pitch when reversed, subtract 63° 26″ from 90°. To do this it must be remembered that it is necessary to borrow one degree from ninety and that one degree is equal to 60″ and should be expressed thus, 89° 60″—63° 26″=26° 34″, which will be seen is the same as that for a 6-inch rise or the one-quarter pitch. (Also see Fig. 196.) By referring to the degree scale in Fig. 197, the degree of the other pitch lines can be very nearly arrived at by scale as shown by the quadrant.

We trust we have made it clear that by using the tongue of the square to represent the run, instead of the blade as is the custom of most other writers, permits of the pitch lines up to the full pitch. Then again the blade being longer than the tongue gives a greater range of angles without reduction from the full scale to obtain the side cuts of the jacks and hips, which with this system are always on the blade, thereby helping to more readily fix on the mind the different cuts and where they belong on the steel square.

What Constitutes a Full Pitch.—We find builders differ as to what constitutes a full pitch, and this is not to be wondered at, because writers on the subject differ. There are a number of books on the market, one of which has reached considerable sale, a copy of which is now before us, illustrating the pitch lines on the square similar to that shown in Fig. 196, but designating each line as a whole, as 1, 2, 3, etc., pitch up to twenty-fourth pitch. Yet the universal theory of

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lines. Now let us look at the figures on the blade of the square, as shown in Fig. 198, and see what

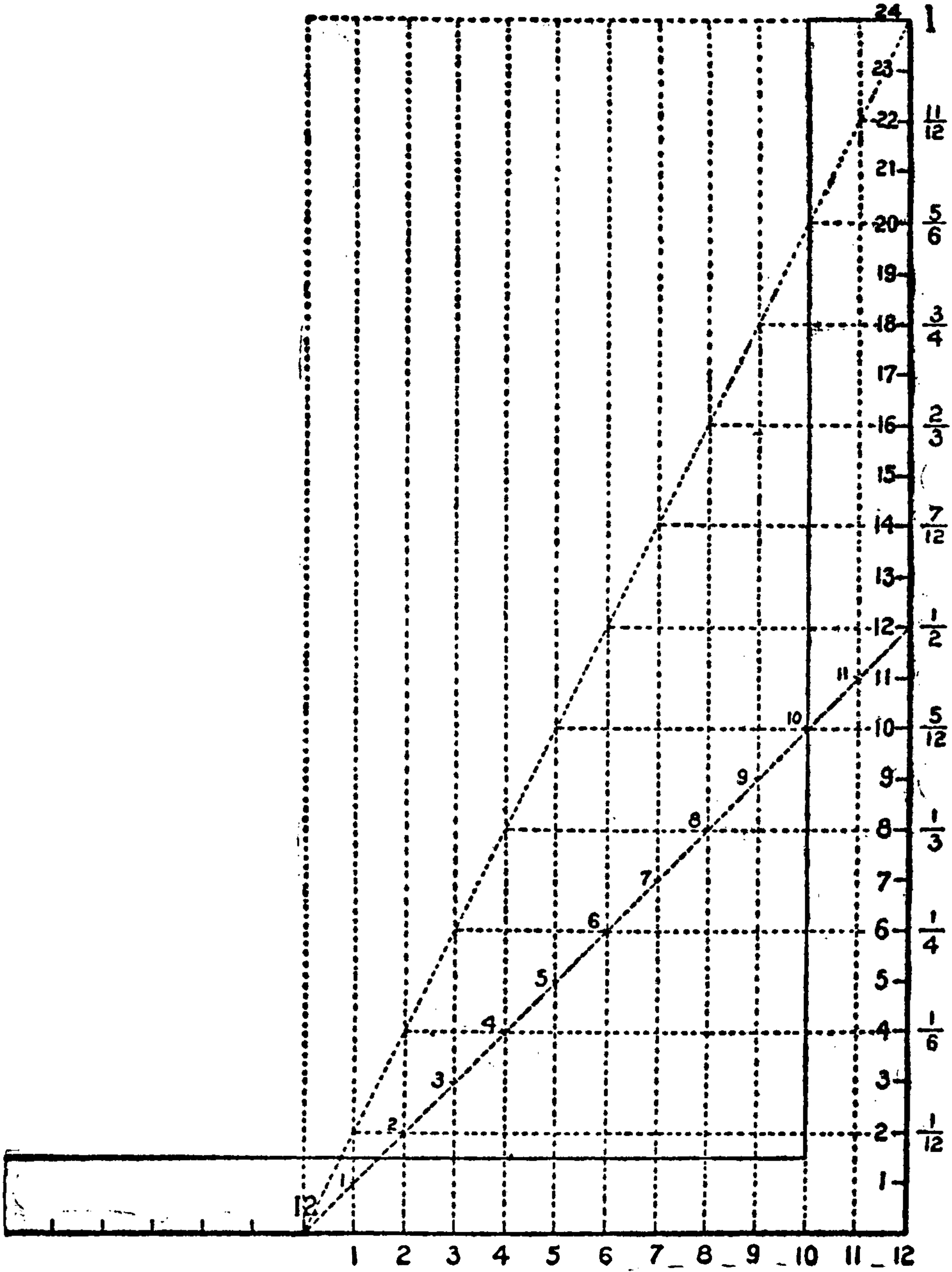

FIG. 198

relation they bear to those on the tongue. These figures as before explained represent the rise

given the common rafter to a one-foot run. The fractional numbers to the right of the blade

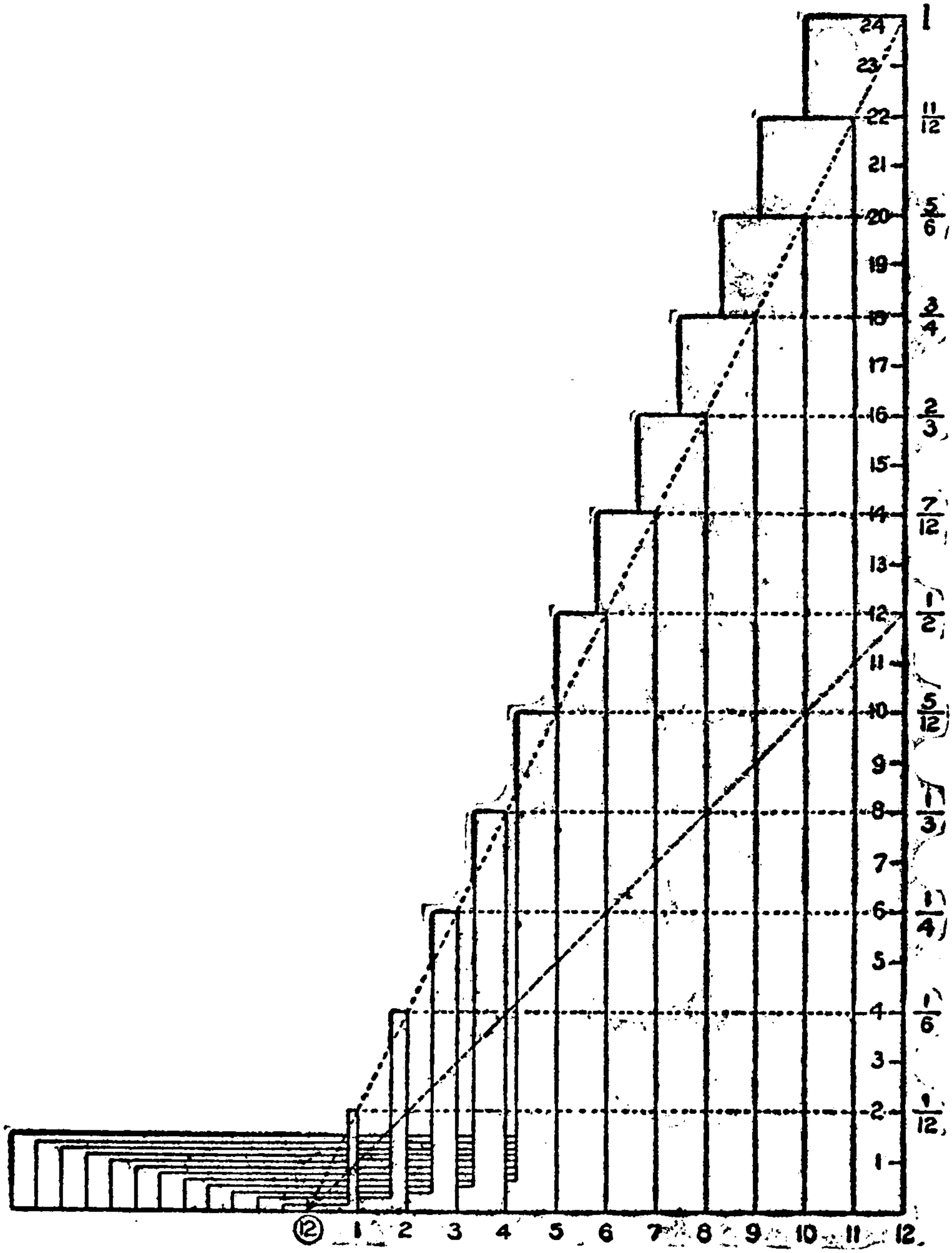

FIG. 199

represent the proportion of the pitch. Now follow the horizontal dotted lines from these figures

over to the full or one pitch, thence down to the desired pitch and the figures at this point and those in the run taken on the square will be to the same proportion as those for the full scale, but at different points on the square. For illustration see the one-half pitch.

In Fig. 199 is shown a similar drawing, but in this the squares are reduced in size ranging from one-twelfth up to the full size square. The fractional figures that denote the pitch, also denote the size of the squares in proportion to the full size square and these, if divided into as many parts as the full size square would give just the same results as far as the cuts and bevels are concerned, as will be seen by taking the one-half pitch, the line passes at the half-way point on the blade of all of the squares and consequently would give like results. However, squares are not made other than with the standard measurements. This illustration is given simply to illustrate proportional scales and that the size of the square would make no difference in the results so long as the divisions are to the ratio of the standard scale of measurements.

But we are not through talking about Fig. 198. In this illustration the vertical dotted lines from each inch in run represent the blade and the figures where the one-half pitch line crosses these lines and that denoting the run will give the seat and plumb cuts for the common rafter, as 1 and 1, 2 and 2, 3 and 3, etc. Now let us apply this to some other pitch. For an example we will

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To find the ¼ scale for the above pitch, take 6 on the blade and follow the horizontal line to the left till it intersects the one pitch, thence vertically down to the ⅜ pitch, and it will be found that this intersection is at 2¼ inches above 3 on the run, and it will be seen that these figures are ¼ that of 9 and 12.

For the 5-12 scale, proceed in like manner, starting from 10 on the blade. The intersection on the pitch line will be 3¾ inches above 5 on the run. Thus every inch of the blade's length represents a distinct scale, and these are subject to many more scales. If the blade of the square be divided in twelfth inches, each division will represent a scale, making in all 12 multiplied by 24, equals 288 different scales; but these divisions run into intricate fractions for the rise, and only one-half of the runs will end in twelfths of an inch. The other half will end in twenty-fourths, but all of these scales will be in the same ratio as that given for the full scale, and consequently give the same result as far as the angles are concerned. However, it is better to use the full scale when

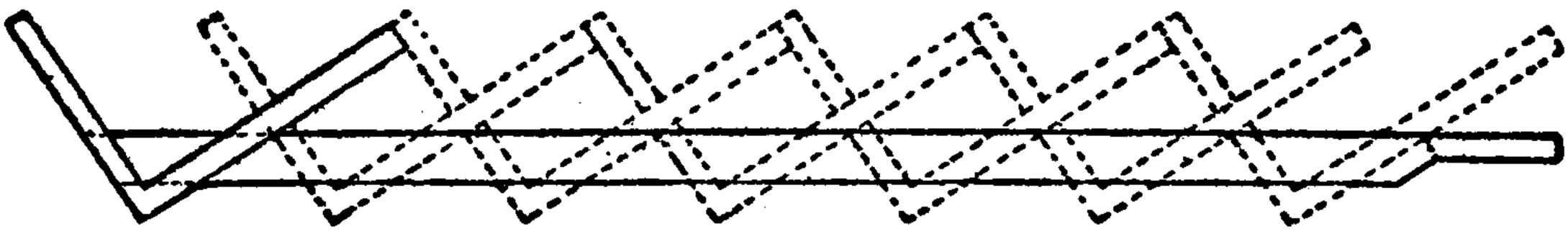

FIG. 201

same can be done, as it is handier and insures more accuracy in the work.

To Cut Rafters with The Square.—Fig. 201 il-

lustrates a way to cut rafters with a square. A roof 14 feet wide would have a run of 7 feet, third-pitch would rise 8 inches to every foot run. Therefore, place the square on 8 and 12 seven times, and you have the length and cuts.

Fig. 202. For the octagon rafter, proceed

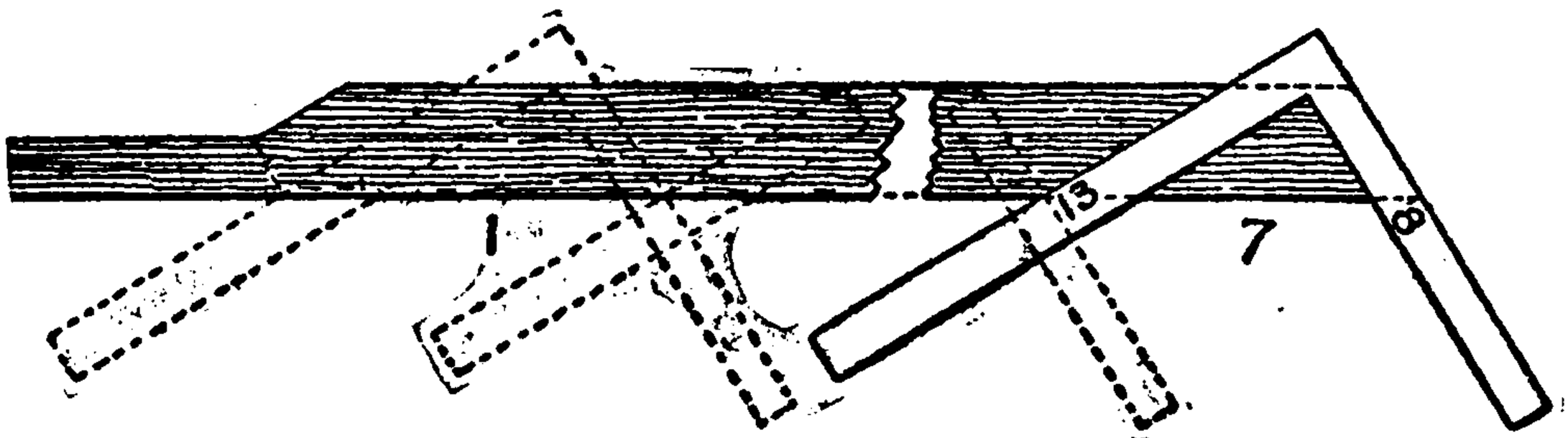

FIG. 202

same as for common rafter, only use 13 for run (in place of 12 for common rafter).

Fig. 203, hip or valley rafter. As these rafters run diagonal with the common rafter and as the

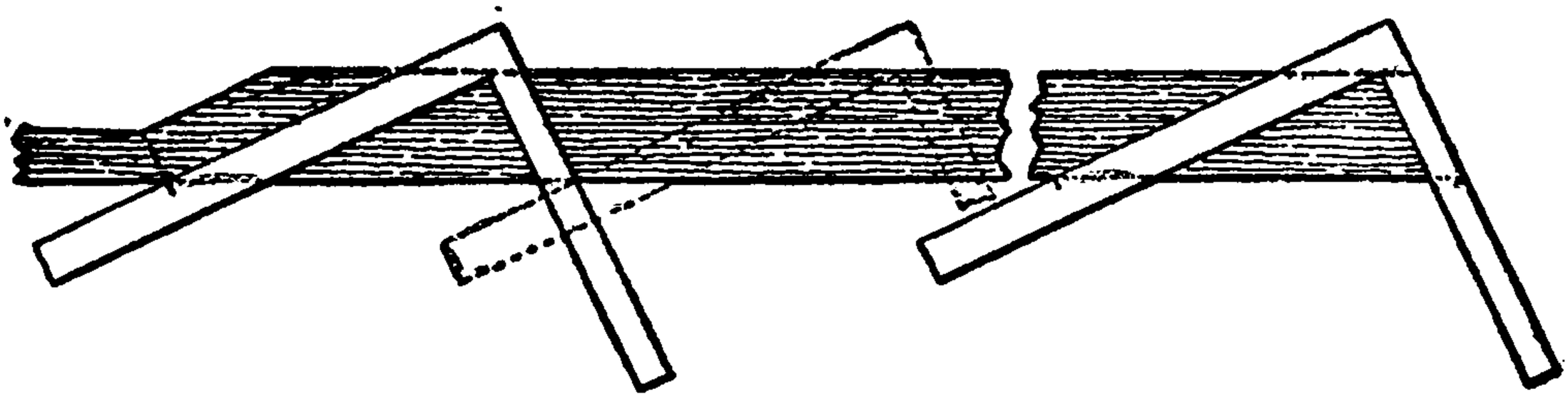

FIG. 203

diagonal of one foot is practically 17 inches, use 17 for run, and proceed the same as for common rafter.

Length of Jacks.—If there are to be five, divide the common rafter into six equal parts, use that for a pattern, and it gives the length very nicely. But that will not always work. To get all the dif-

ferent lengths might at first, look difficult even to many good mechanics, but it is very simple as

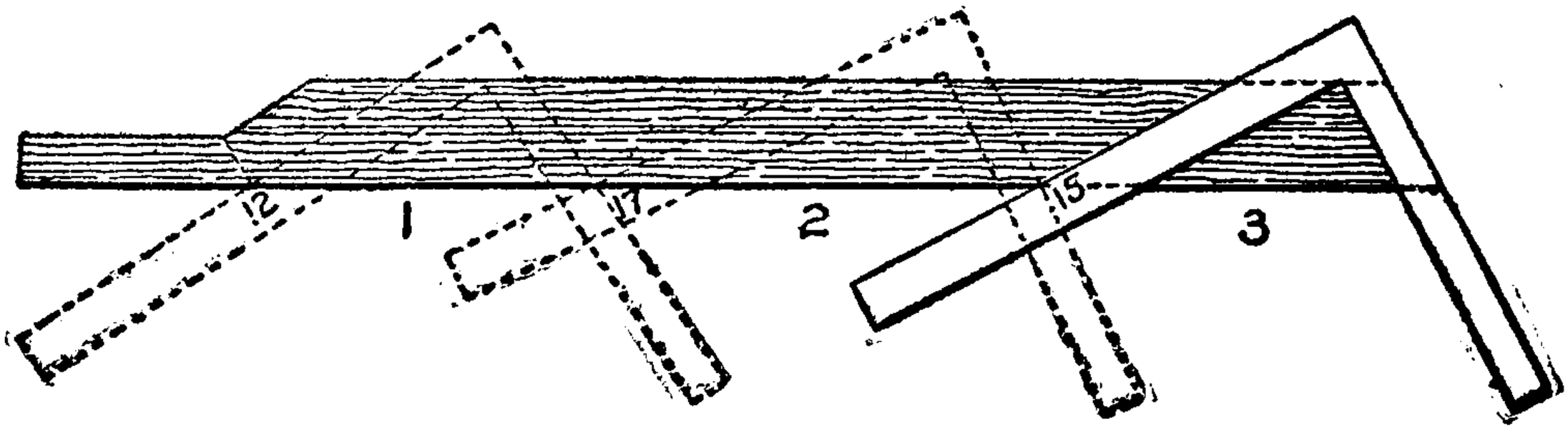

FIG. 204

illustrated in Fig. 204. If the first jack was one foot from corner, apply the square the same as for common rafter, and it gives length and cut (mark the length for starting point on next), and if it is 17 inches from the other, move the square up to 17, if the next is 15 move up to 15 and so on.

Fig. 205. The side cut of jack to fit hip, if laid down level would, of course, be square miter,

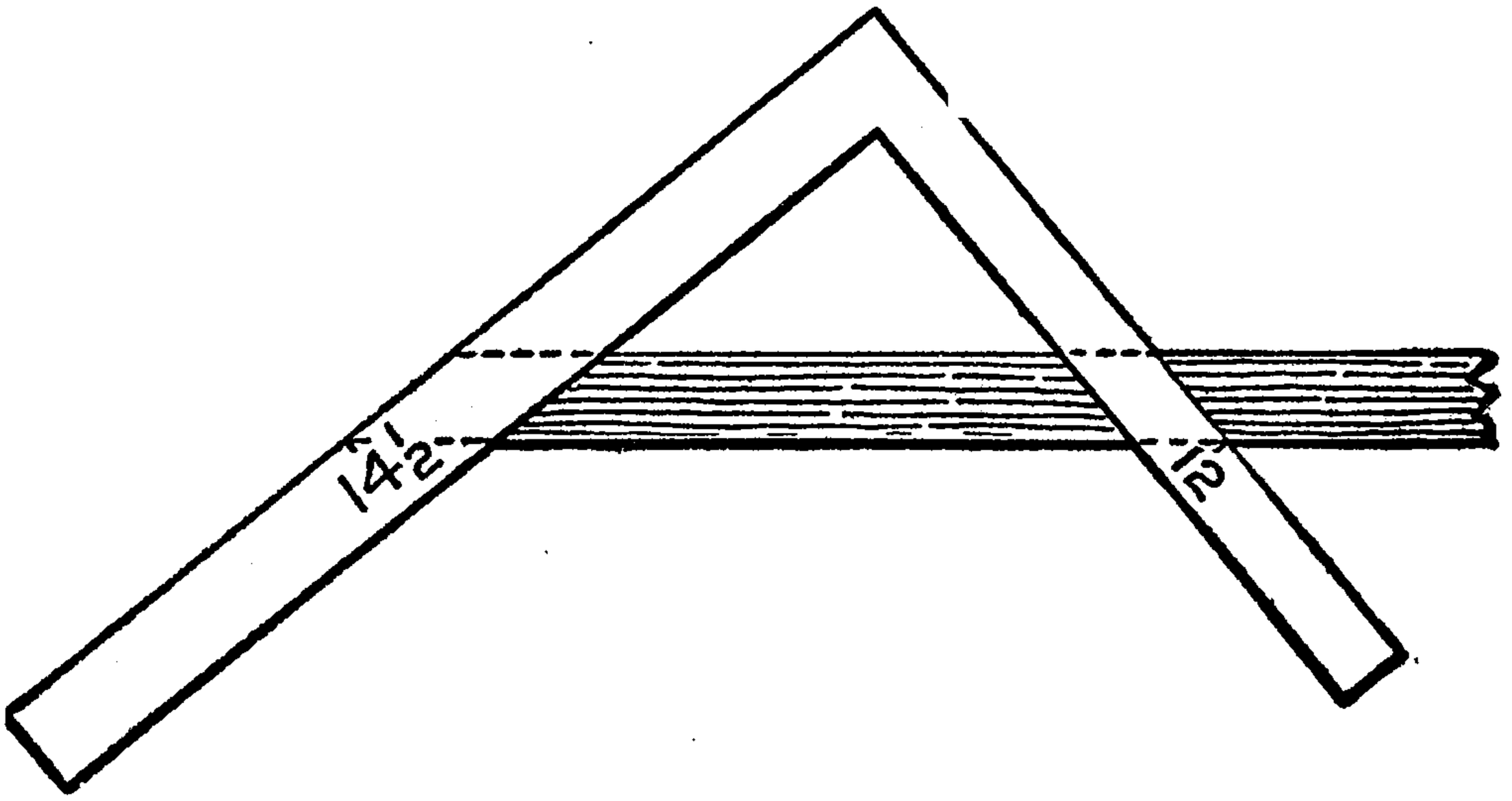

FIG. 205

but the more the hip rises the sharper the angle. Measure across the square from 8 to 12, and it is

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Fig. 207, hip rafter, is also length and run, cut on length.

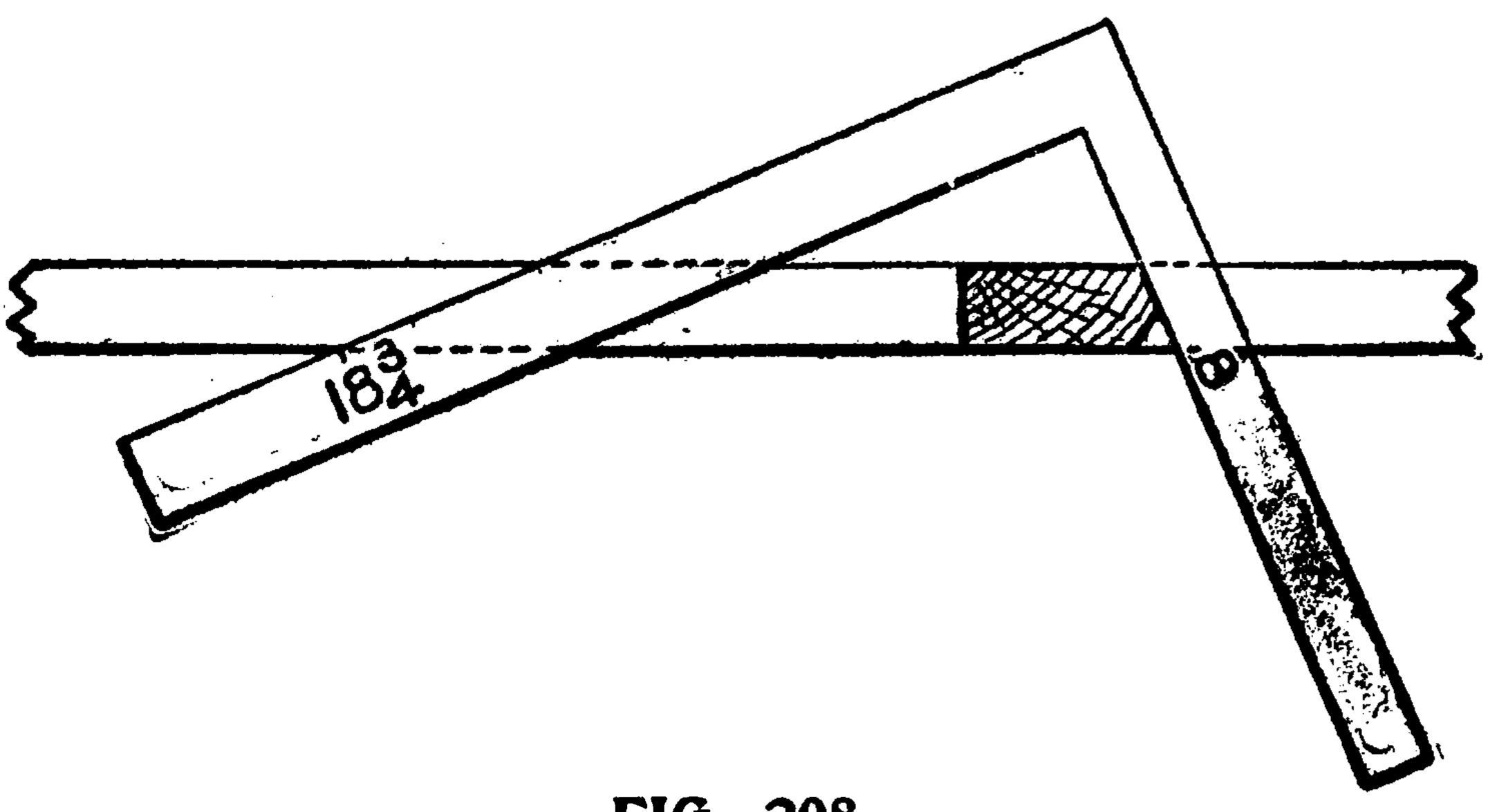

FIG. 208

Fig. 208. To bevel top of hip take length and rise and mark on rise.

Fig. 209 is another practical way, which is

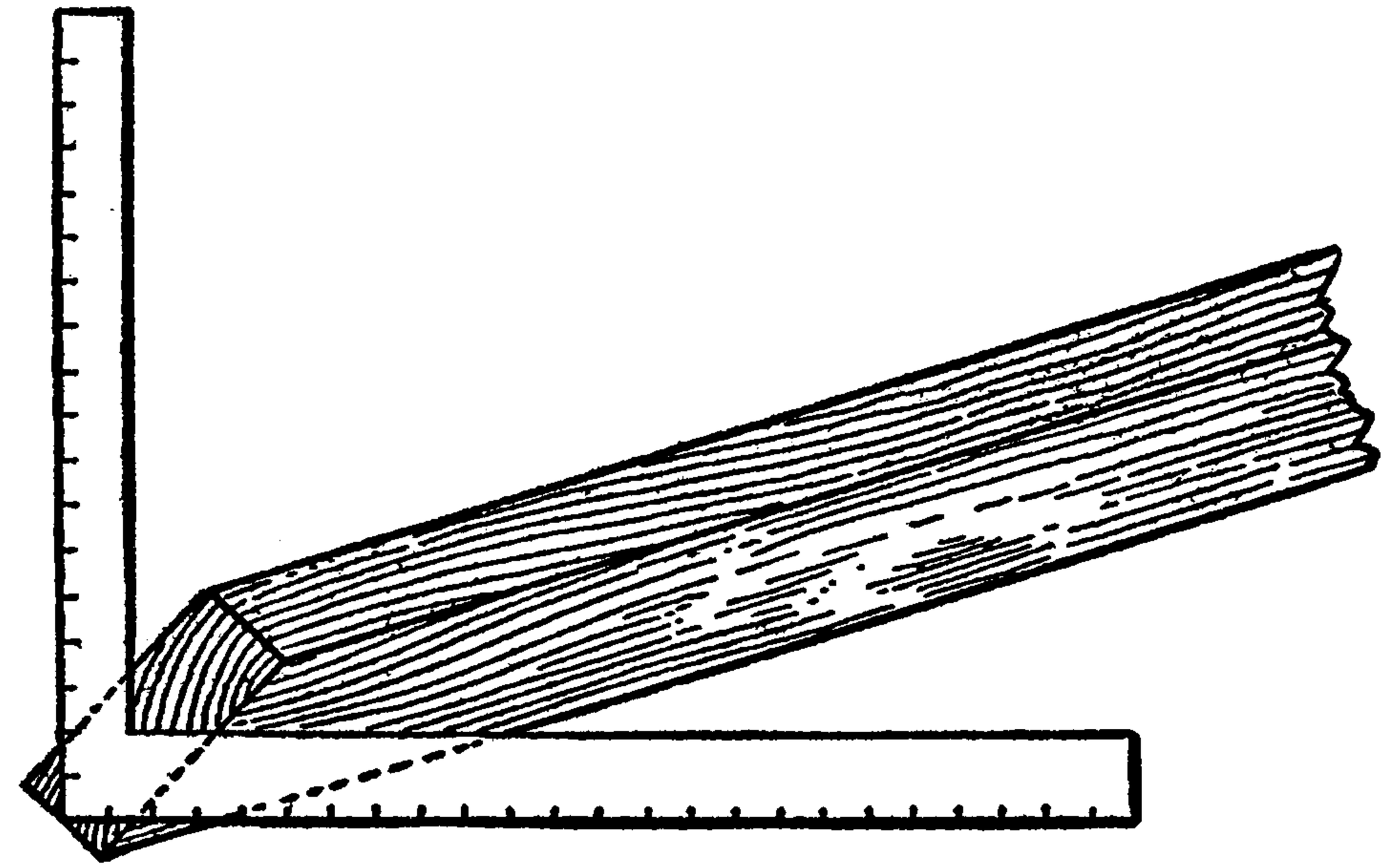

FIG. 209

simply to lay the square on heel of hip. The illustration explains itself.

Simplest Way to Frame a Roof.—Perhaps the most practical way of all to frame a roof, the simplest to understand, easiest to remember, and most rapid to apply, is simply to always take the rise and run, measure across the square which gives the length. Rise and run gives cuts, so you have it all.

Fig. 210 illustrates a roof 25 feet wide and a

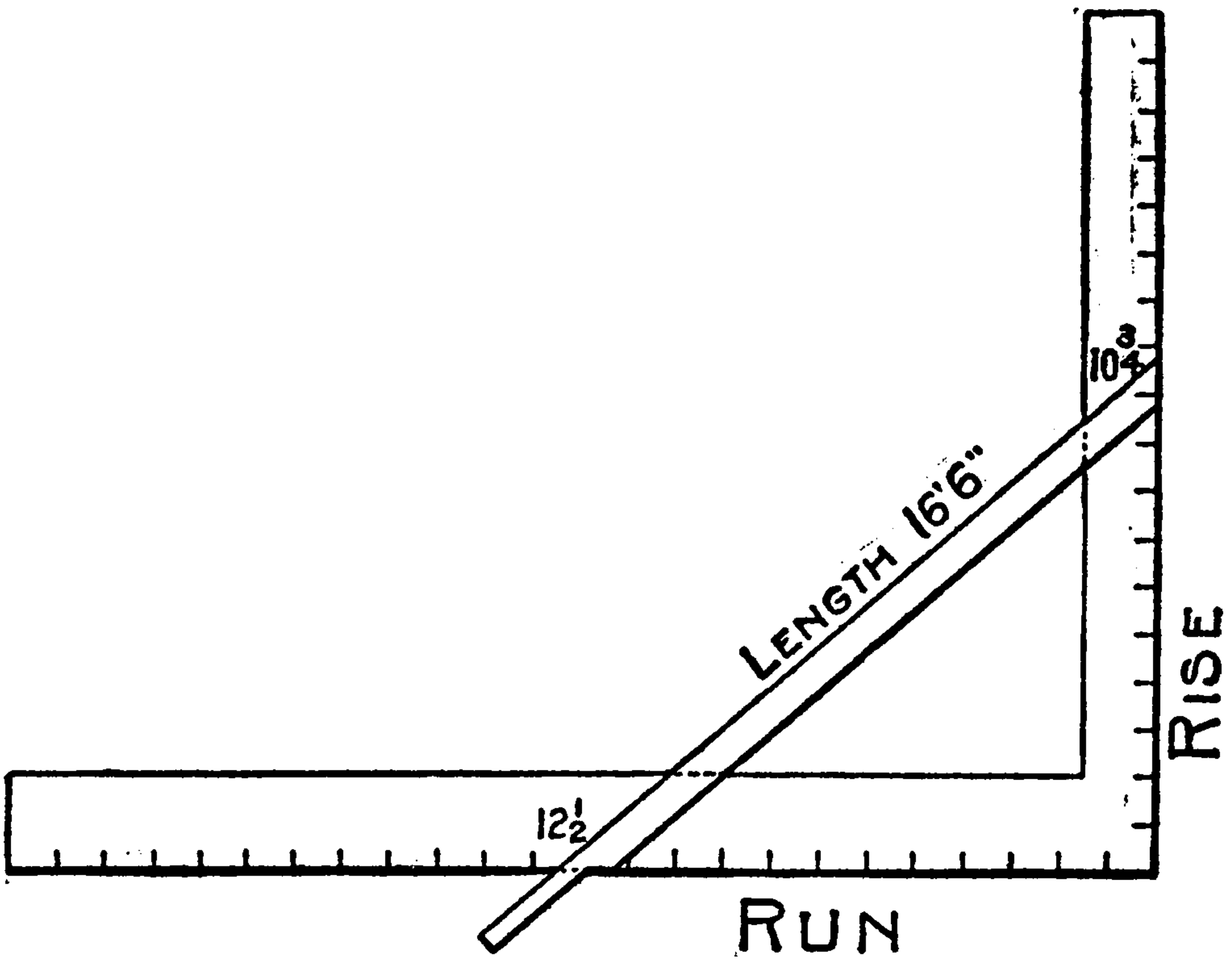

FIG. 210

rise 10 feet 9 inches, run 12 feet 6 inches. Measuring across the square from 10¾ to 12½ gives 16½, or 16 feet 6 inches is the length of rafter.

Fig. 211. If the run of common rafter is 12½, the run of the hip will be diagonal of 12½, which is 17 and 8-12, as is plainly illustrated.

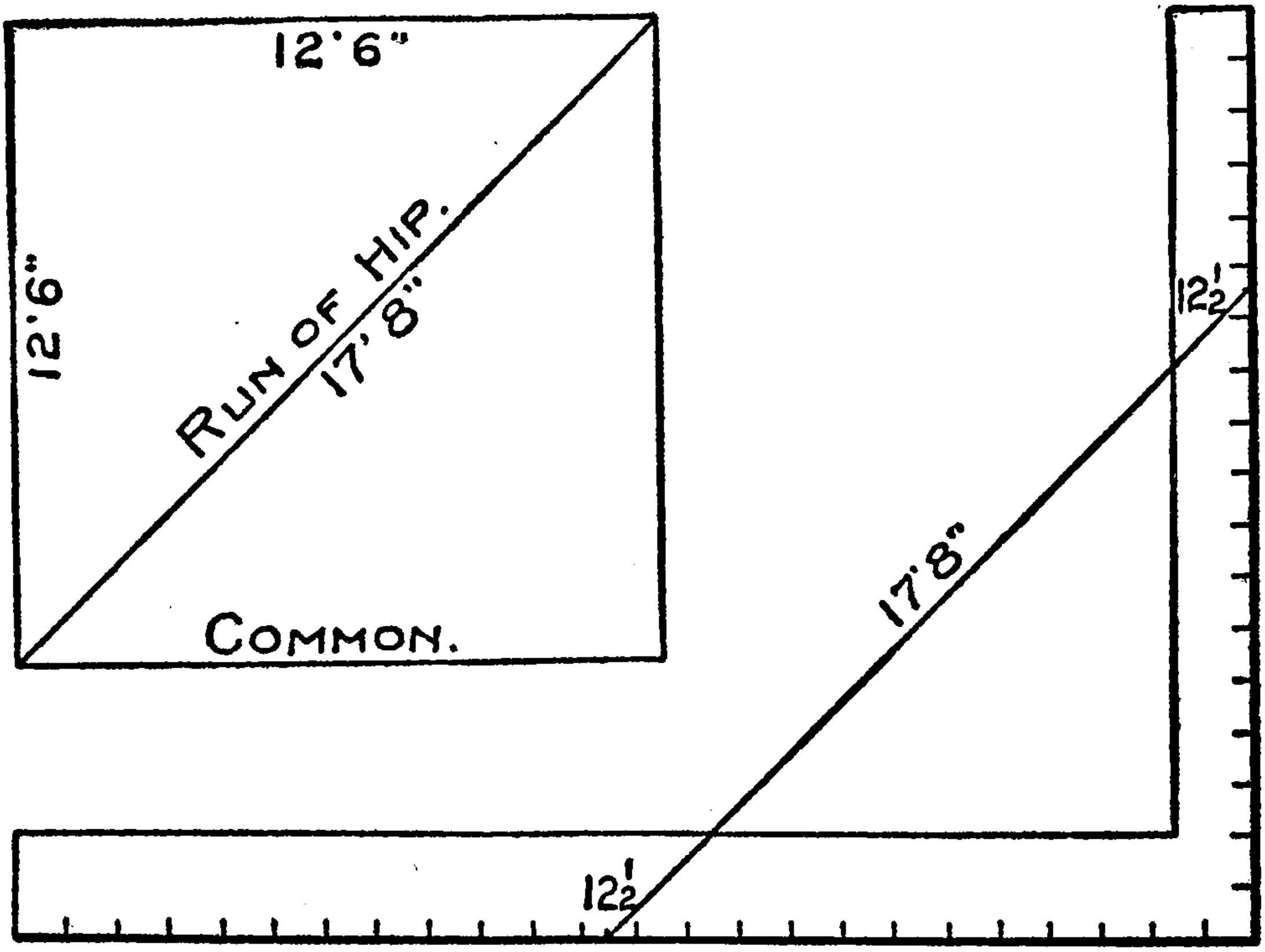

FIG. 211

Fig. 212. As the rise is $10\frac{3}{4}$ and run 17 and 8-12, the length will be 20 feet and 2 inches.

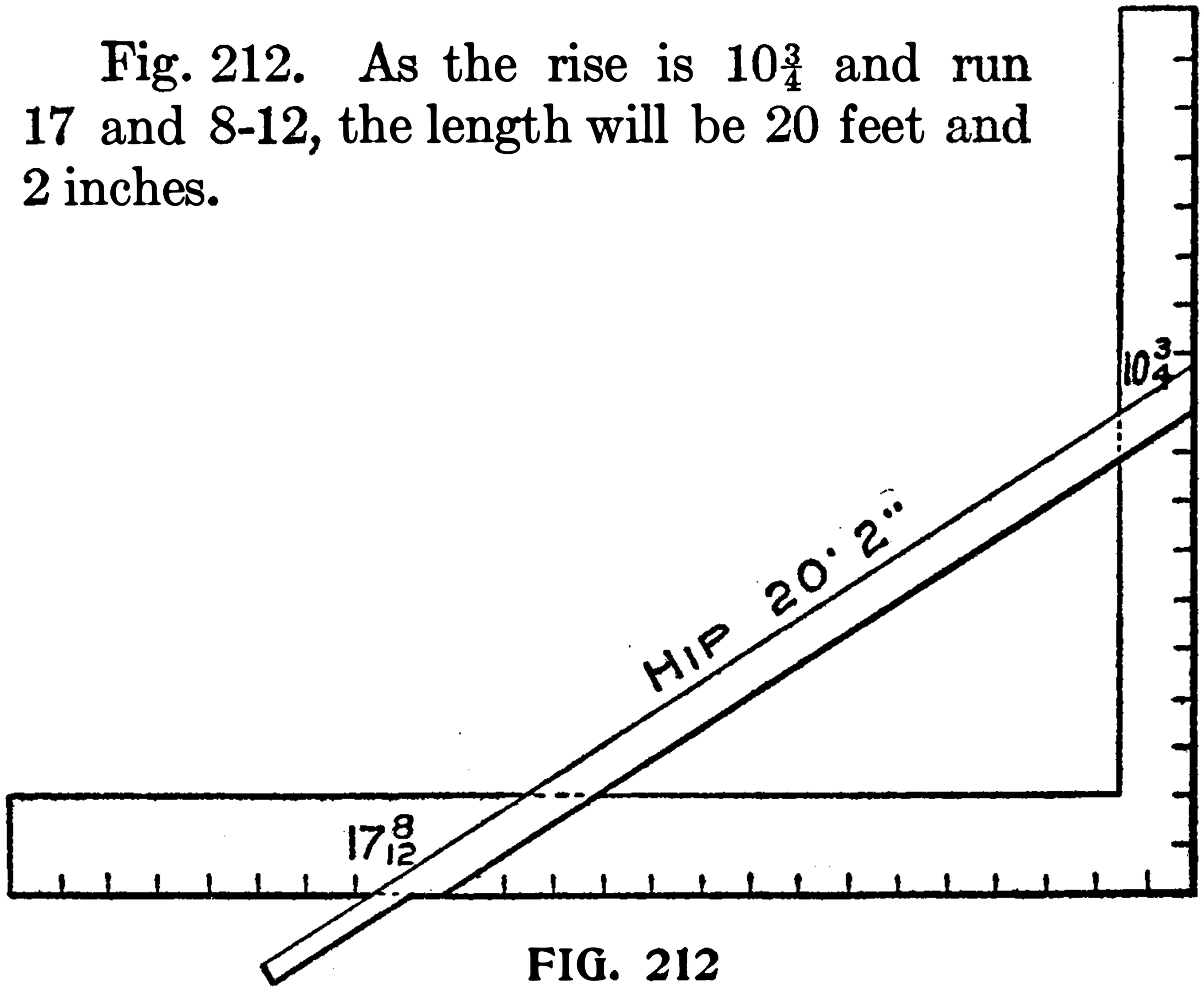

FIG. 212

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Fig. 214 illustrates the cut of top of quarter-pitch rafter to lay on top of roof just mentioned. To apply square, first lay it on 12 and 6, which is quarter-pitch, and gives plumb-cut. From plumb-cut lay off pitch of main roof $10\frac{3}{4}$ and $12\frac{1}{2}$, which gives cut.

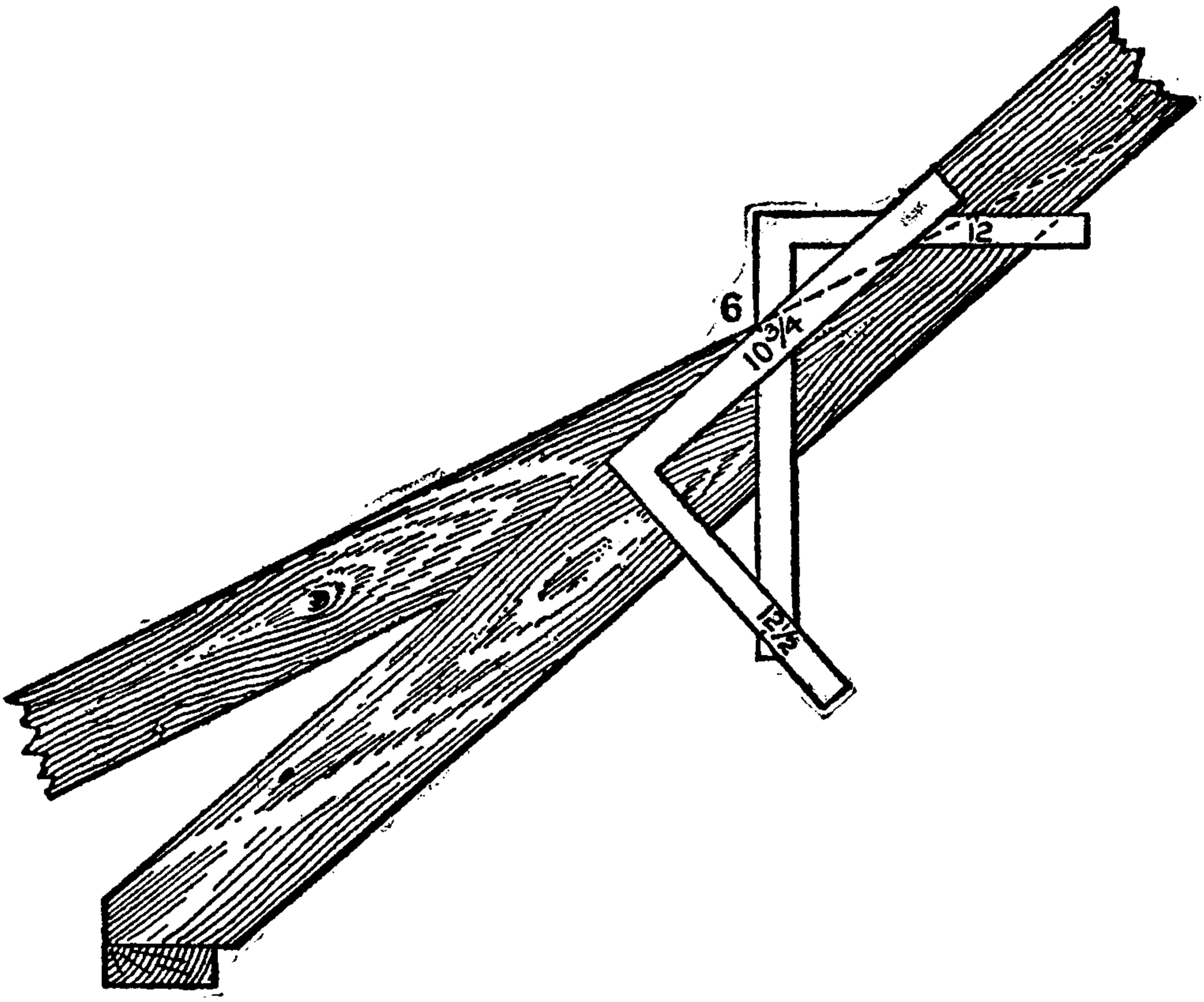

FIG. 214

It is quite clear that a common rafter becomes a hip for a building of less span, as will be seen by referring to Fig. 215. Here the common rafter for a 12-inch run becomes a hip for an $8\frac{1}{2}$ inch run. A hip for a 12-inch run becomes a common rafter for a 17-inch run. Therefore, the same rule must apply to both, that is, the tangent (commonly called

run) and rise, taken to scale on the square will give the seat and plumb cuts. The tangent and the length of the rafter taken to scale on the steel square will give the side cut for the hip to rest

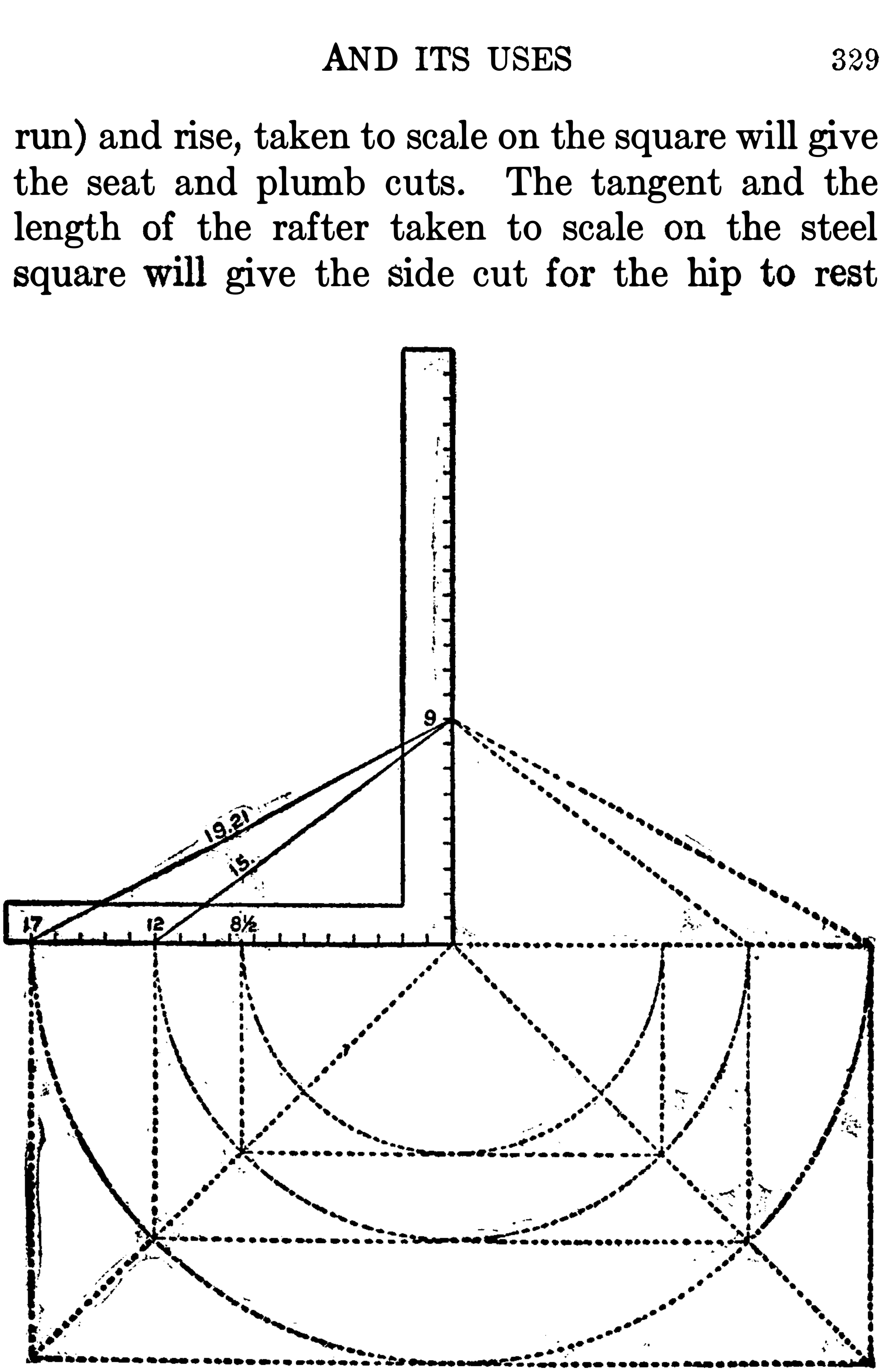

FIG. 215

against the ridge tree. Cut on length. The same applies for the common rafter, which gives the side cut of the jack to rest against the hip or valley.

Taking the full scale for the hip as compared with the common rafter, it is practically 17 on the tongue and the length of the hip for a one-foot run of the gable taken on the blade, and the latter will give the cut. If 12 is used on the tongue for

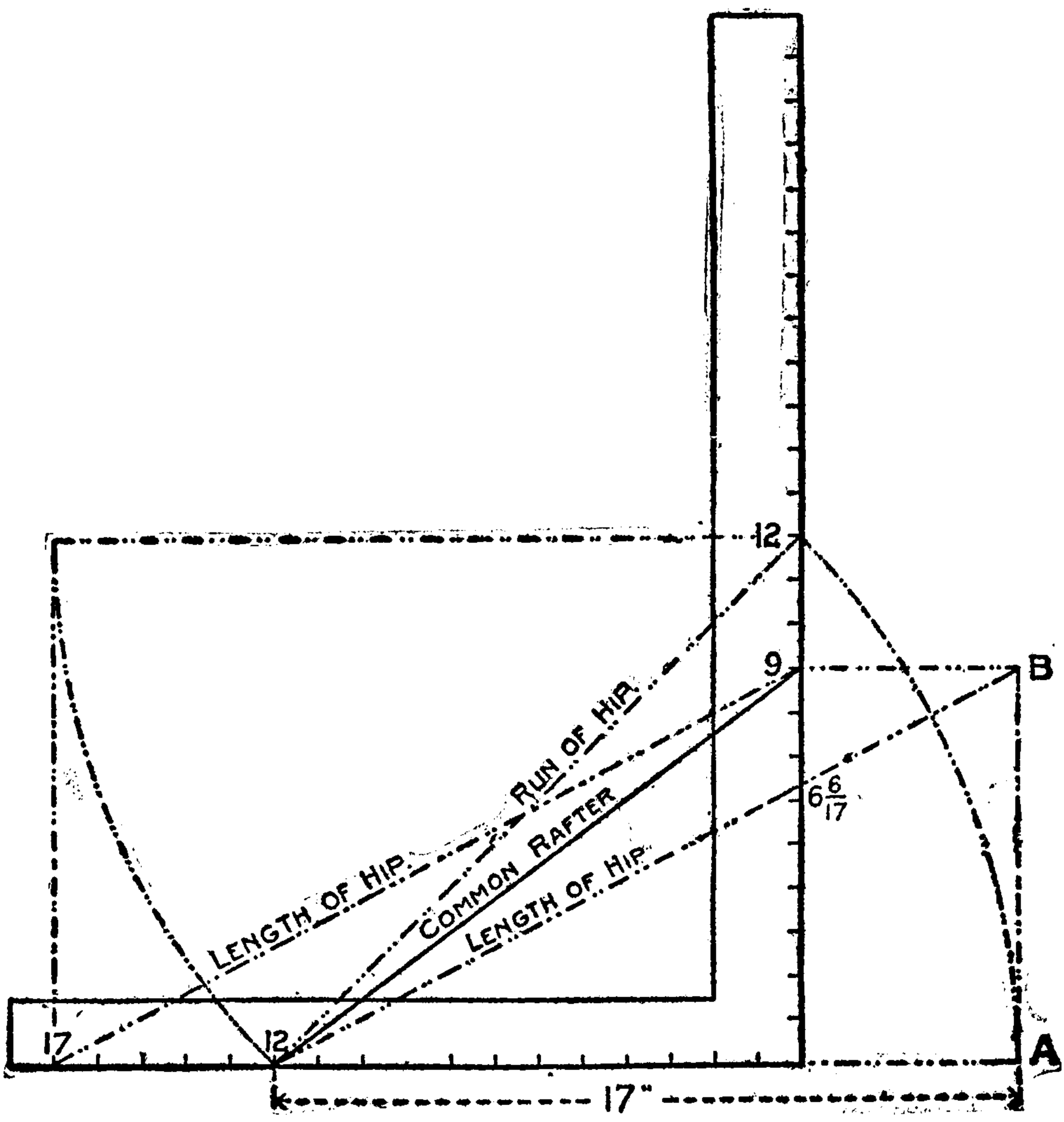

FIG. 216

a foot run of the hip, its rise would necessarily be less than for the same run of the common rafter, as will be seen on Fig. 216. In this is shown the corresponding difference for the ⅜ pitch. The

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inch of being 17 inches. This, however, is too small to consider, but the lengths of the rafters for accuracy should be reckoned from 16.97 inches.

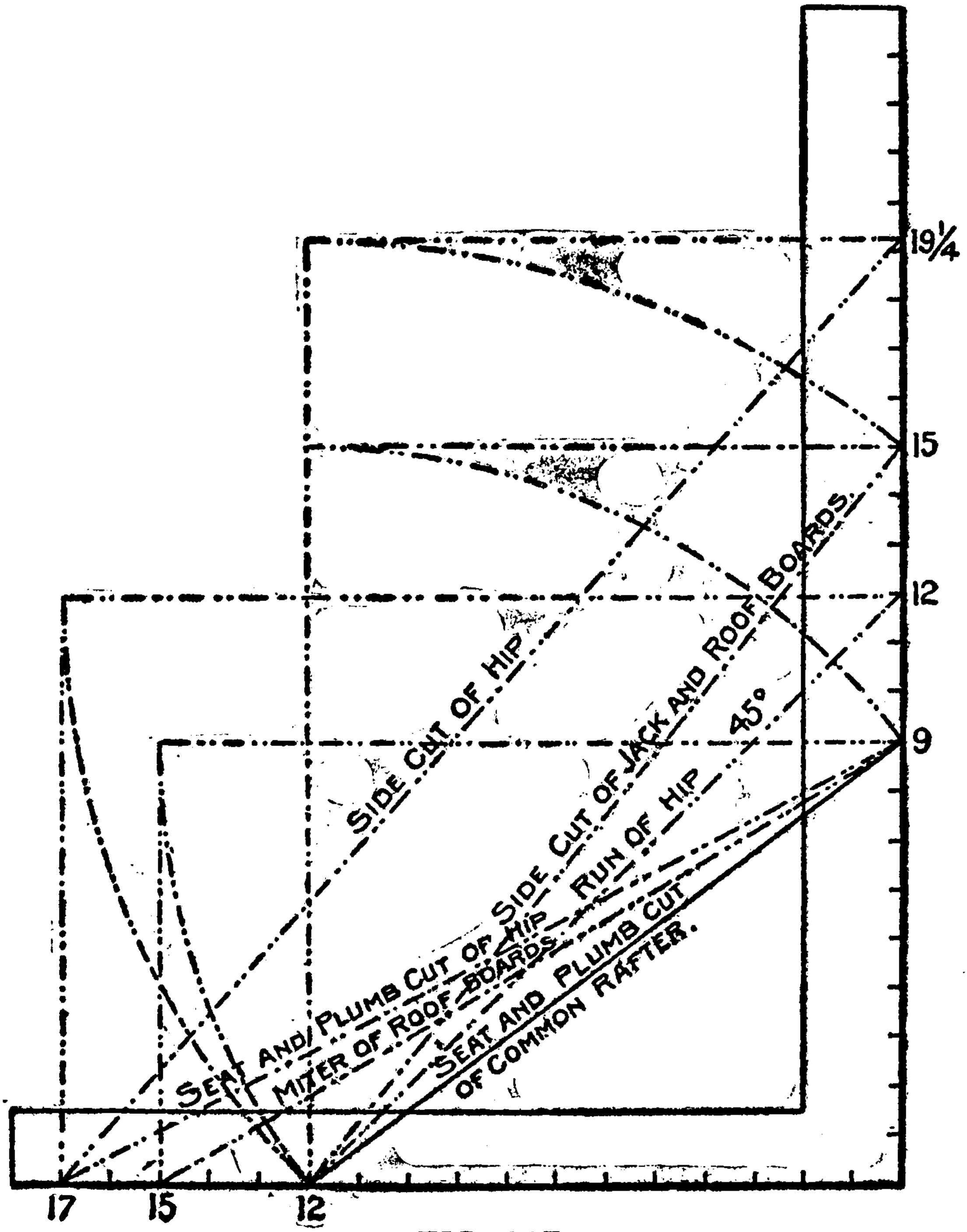

FIG. 217

In the foregoing, we have tried to lead up more to the cause and effect and have in a general way

touched on the different cuts about the roof, showing at the same time why they give correct results.

We will now take up the subject showing the various cuts in one diagram as shown in Fig. 217. Here are shown the measurements on the steel square.

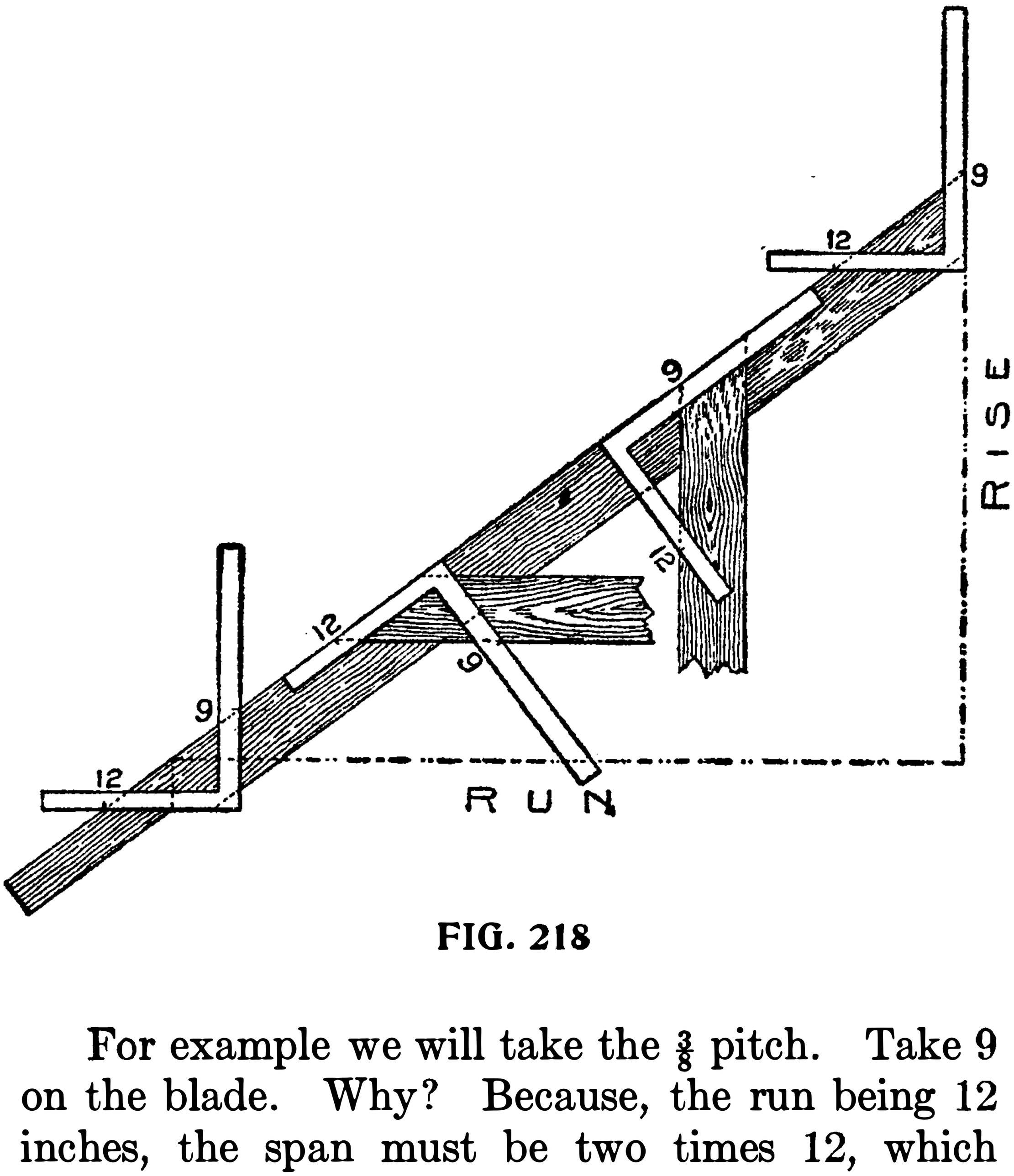

FIG. 218

For example we will take the $\frac{3}{8}$ pitch. Take 9 on the blade. Why? Because, the run being 12 inches, the span must be two times 12, which equals 24, and since the pitch is reckoned by the span, we find that $\frac{3}{8}$ of 24 is 9, and therefore rep-

resents the rise to the foot run. Then 12 and 9 gives the seat and plumb cut of the common rafter. They also give the cuts for the gable boards resting either horizontally or perpendicularly as shown in Fig. 218.

The Cuts, Lengths and Bevels of Rafters are all contained in the cube as shown in Fig. 219. The base of the cube being twelve inches square, while

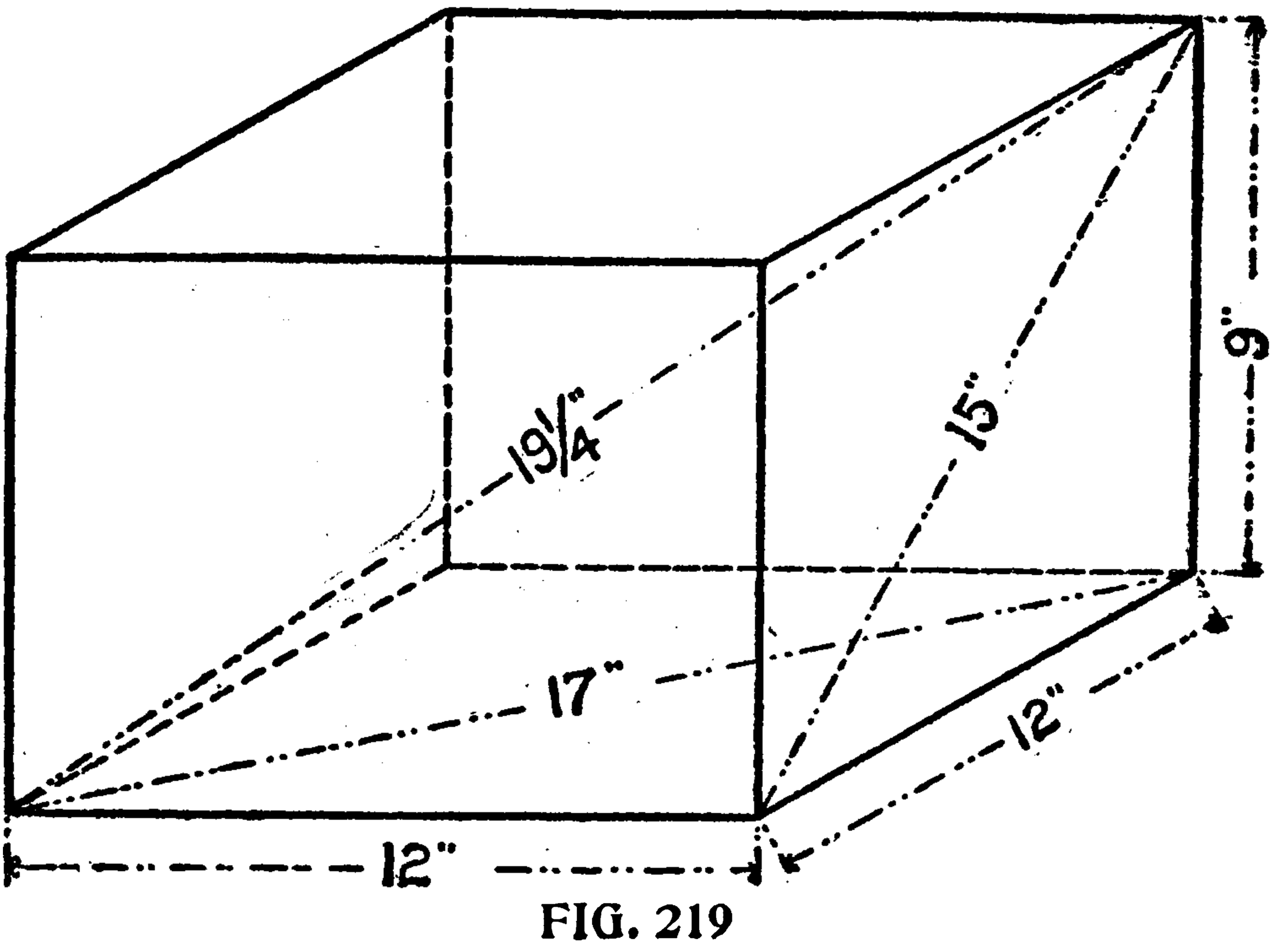

FIG. 219

the altitude is regulated by the rise given the common rafter to a one-foot run, which in this case is 9 inches or ⅜ pitch. This is one of the best methods of fixing on the mind the true position of the different rafters and why certain figures are used on the square to obtain the cuts. We will carry this thought a little further and show the corner of a hip roof in an imaginary cube with dimensions

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In fact it would show just the same if there was no pitch given at all, consequently all of the angles for the side cuts are at an angle of 45 degrees. If there was no pitch, it would simply be the common miter of 12 and 12 on the steel square, 12 being used

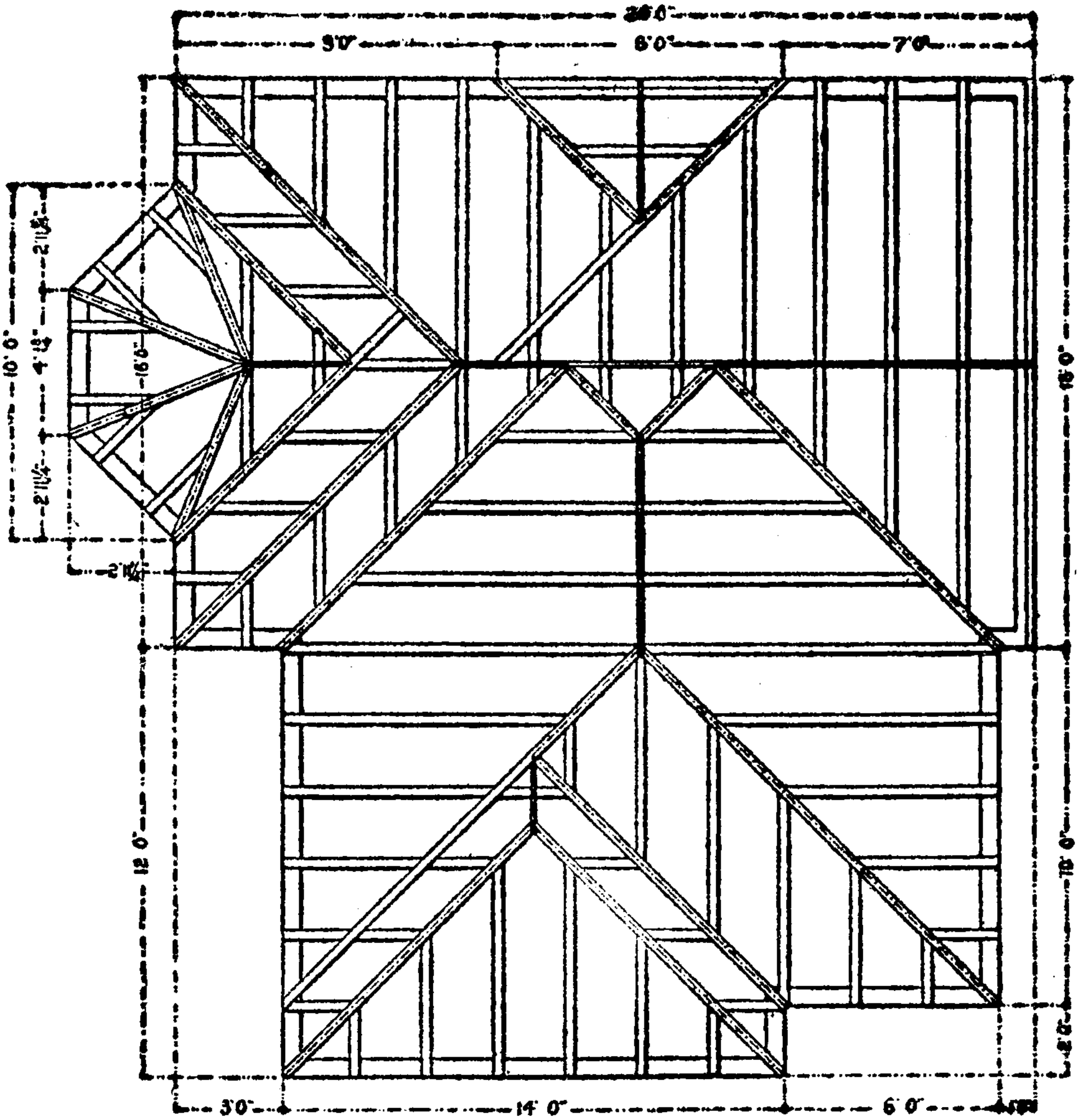

FIG. 221

on one arm of the square because it represents the length of the tangent when the run is one foot and remains so regardless of the pitch given the roof. 12 is used on the other arm of the square because

it represents the length of the rafter for one-foot run when there is no pitch given. Therefore, we let 12 on the tongue represent the tangent because it is a fixed number and answers for any pitch. When there is a pitch given the rafter, its length is increased. Thus, in the $\frac{3}{8}$ pitch, the length is 15 inches. Therefore, 12 on the tongue and 15 on the blade gives the side cut of the jack as before illustrated. If we were to cut off the peak end of the jack rafter on a parallel line with the seat cut after the side cut has been made, the angle would show just what we started from—the 45-degree angle. For the side cut of the hip, it would be 12 and 6 6-17, but in order to avoid the fractions it is better to use 17 on the tongue, as described in connection with the above figure.

The run and tangent in the case of the square cornered building being equal is very misleading. 12 taken on one arm of the square is generally ascribed to the run, when, as a matter of fact, it has nothing to do with it. The run of the rafter and its length (which gives the same result as 12 on the tongue and the length of the rafter for a one-foot run taken on the blade) gives the side cut of the jack rafter for the square-cornered building and no other. Not because 12 stands for one-foot run of the common rafter, as is generally supposed, but because the tangent equals the run, and is therefore not a general rule, but one of the things that centralizes at 45 degrees.

Now let us apply our unity rule, which, as will be seen, applies to any kind of a corner, whether

square or any other shape. The rule applies to all alike. It is the tangent or the figures on the blade that give the miter when 12 is used on the tongue. These figures transferred to the tongue, and the length of the common rafter for a one-foot run of the given pitch taken on the blade will give the cut. The blade giving the cut. Now, for an octagon roof. The tangent for the octagon is 4 23-24 or practically 5 inches. This taken on the

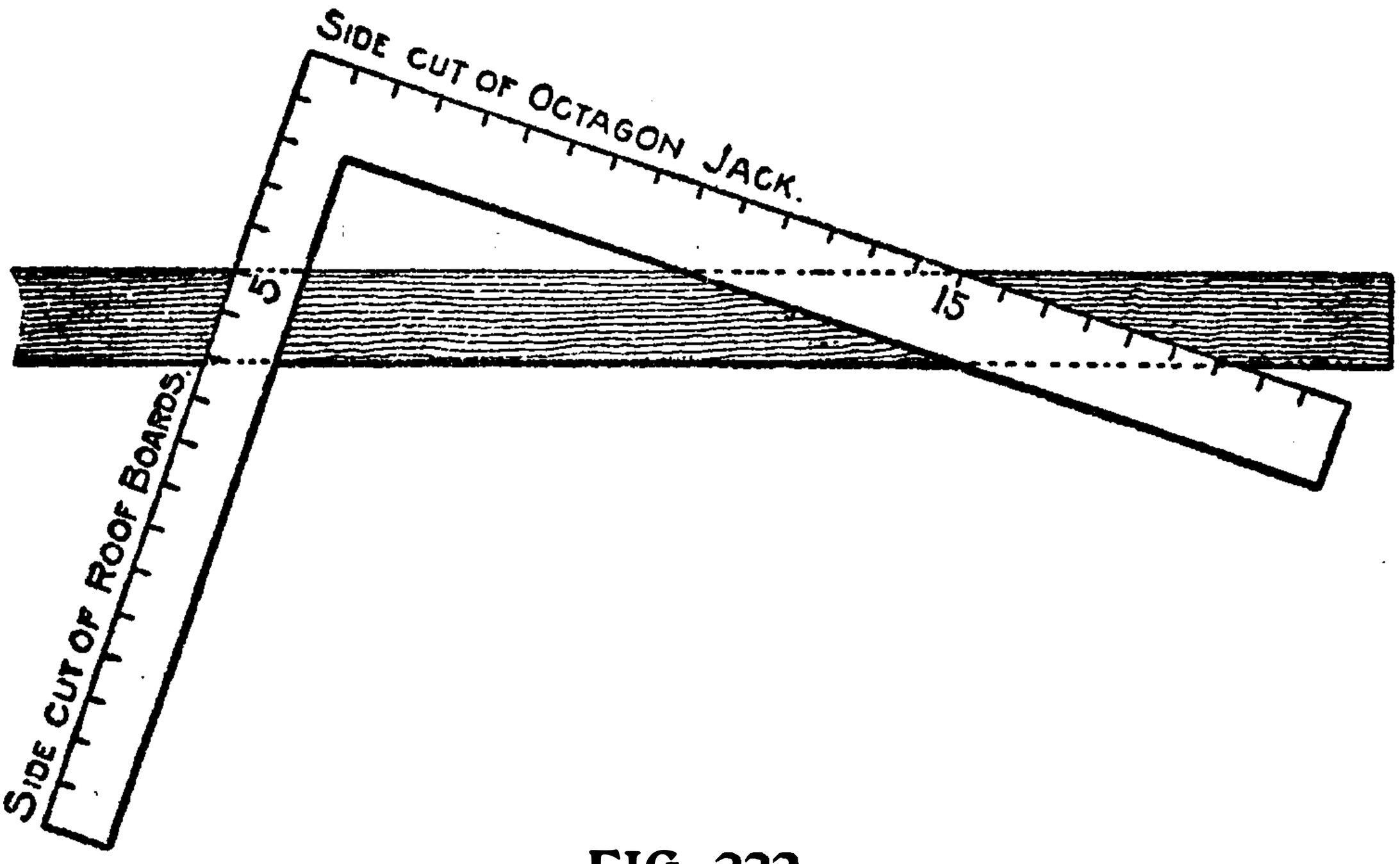

FIG. 222

tongue and 15 (the length of the rafter for the $\frac{3}{8}$ pitch) on the blade gives the side cut of the jack, and the corresponding cut across the face of the roof board to fit over the hip. The blade giving the cut in the former and the tongue in the latter, as shown in Fig. 222.

What is true of this, is true of any other polygonal roof. In Fig. 223 we show the tangents on the blade for the polygons from 4 to 10 and rep-

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Measurement Line of All Jacks, Hips and Valleys.—The true measurement line of all jacks, hips and valleys is at a line along the center of the back, and just where to place the square on the side of the rafter so as to make the cuts and length come right at that point is a question that taxes the skill of most carpenters, especially so in the

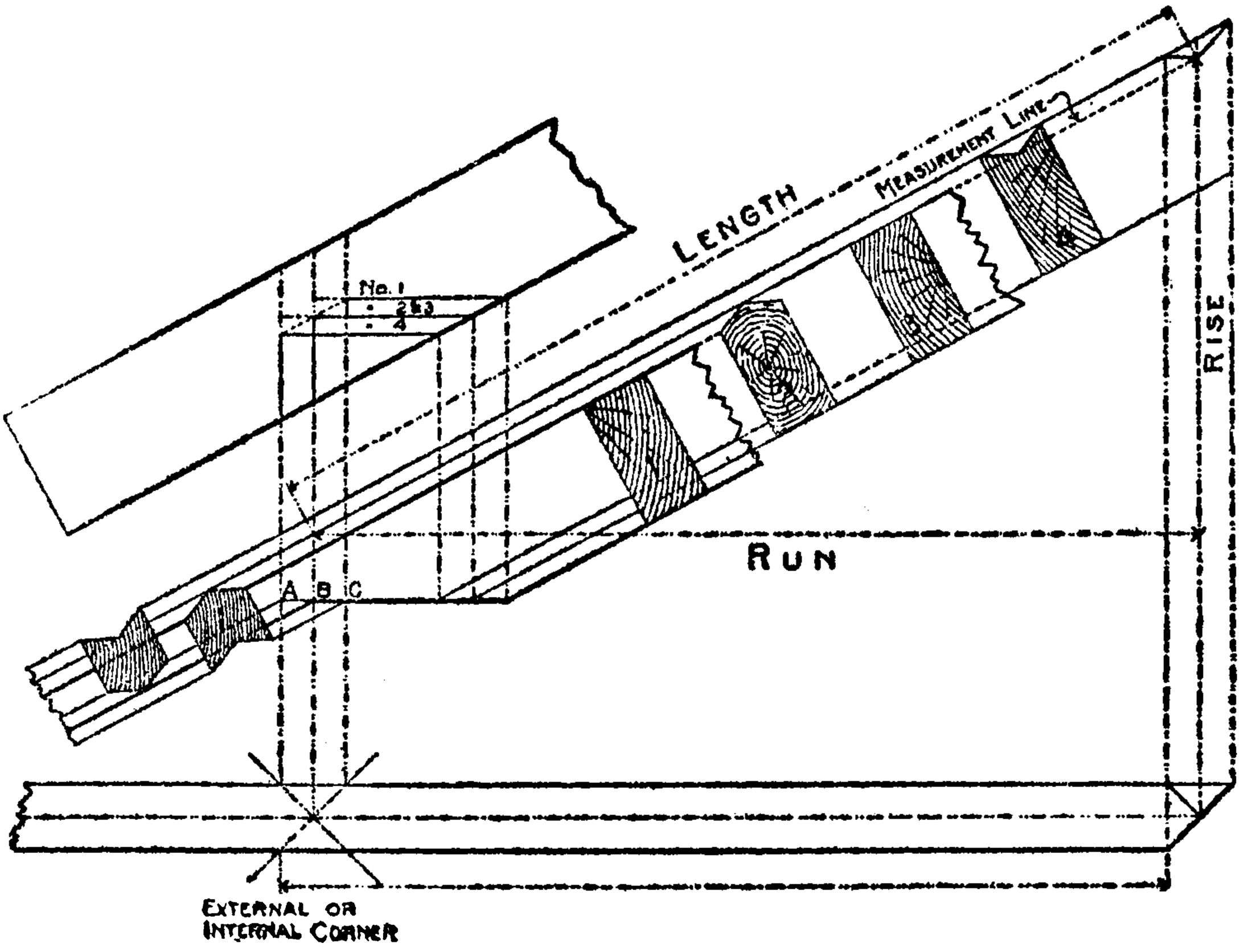

FIG. 224

case of the latter, where the same are to be backed.

In Fig. 224 we show the hip and valley under different conditions for a square-cornered building. Beginning at the bottom is shown the plan of the rafter. The cross lines on same represent the angle of the plates for either hip or valley. Above the plan is shown the elevation. The sections 1-2-3-4

represent the position of the rafters under the following conditions:

No. 1, hip when not backed; No. 2, hip when backed; No. 3, valley when not backed; No. 4, valley when backed. No. 1 is outlined by heavy lines and apparently sets lower than the others. By tracing the bottom line of the sections down to the seat of No. 1, thence up to the second elevation, will show just how far in the seat cut should be for each rafter. No. 1 cuts into the right-hand vertical line above the plan, as at C, which would make it stand at the right height above the plate, at the outer edge of the rafter, but in order to make the seat cut clear the corner of plate, it is necessary to cut into the center line B. No. 2 cuts into the same point as No. 1 ,but owing to its being backed, the seat cut drops accordingly. No. 3, which is for the unbacked valley, also cuts into the center vertical line, and in order to clear the edges of the plate, must cut out at the sides to the left vertical line. No. 4 cuts in the same depth as the latter, but as much lower than Nos. 2 and 3 as they are below No. 1. The vertical lines "A" and "C" from the plan represent the width of the rafter. Therefore, if the rafter be two inches thick, the lines A-B-C would be one inch apart, and this amount set off along the seat cut, or a line parallel with it, will give the gauge point on the side of the rafter. To make this clearer, we refer to Fig.225. 17 and 9 give the seat cut. Now leaving the square rest as it is, measure back from 17 one-half the thickness of the rafter, which would locate the

gauge point at 16, and this will be the point for the line from which to remove the wood back to the center line of the hip. The measurement from the

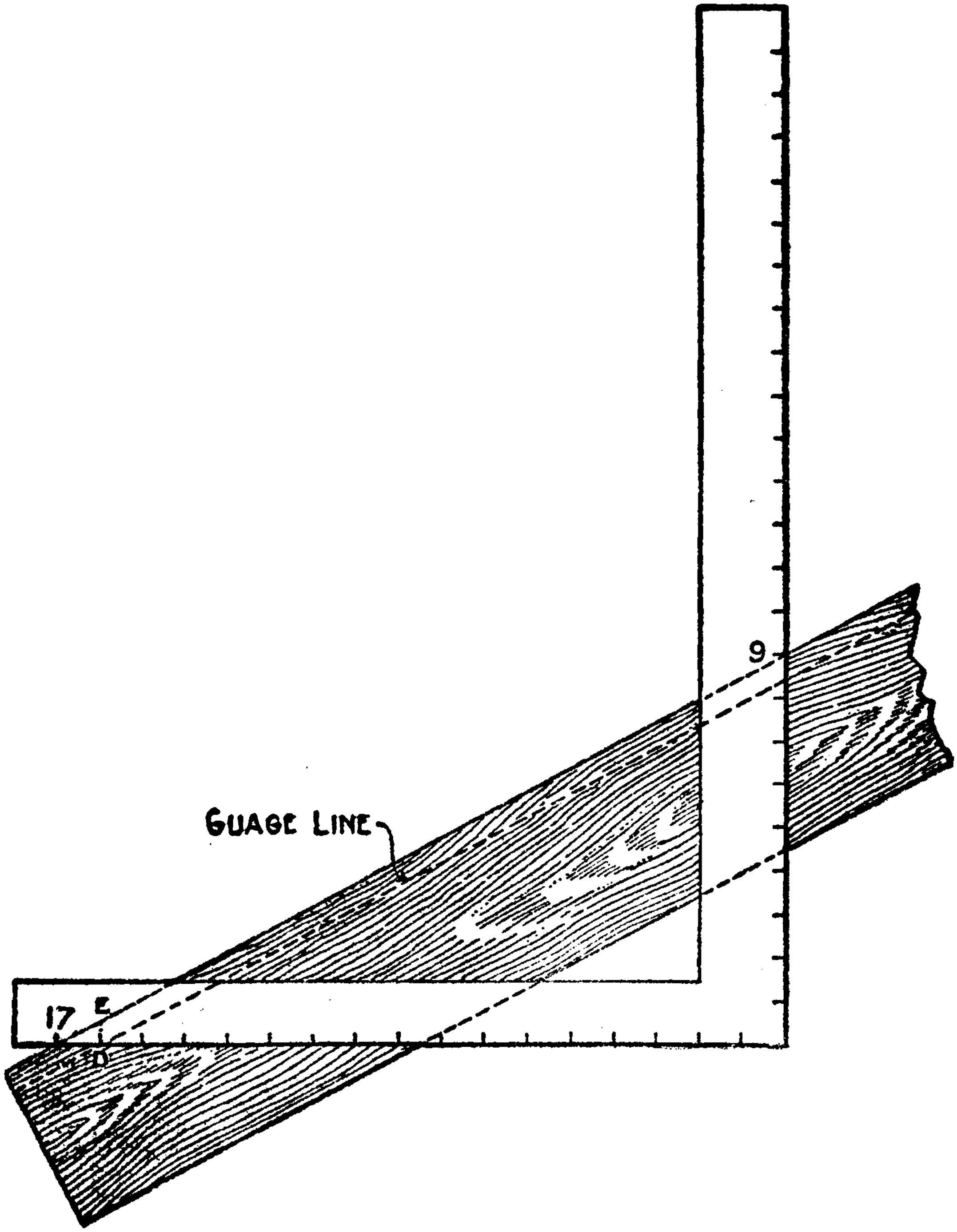

FIG. 225

gauge point taken square out from the seat cut to the edge of the rafter as shown at D-E, shows how

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same as that for the hip resting on a square corner, which is shown in Fig. 225. In this 17 and 9 give the seat and plumb cuts for the $\frac{3}{8}$ pitch while 13 and 9 give the corresponding cuts for the octagon hip. In the former a point 12 twelfths or one inch, is taken back from the edge of the rafter along the seat cut for the gauge line, while in the latter, the point is taken 5 twelfths back. The backing for any other polygonal hip may be readily found in the same way by setting off the tangent for one-half the thickness of the hip. Thus for the hip resting on a square corner, the tangent is equal to one-half of the thickness. In other words, the amounts to set off are the same figures as those used to obtain the side cut for the corresponding jack (see the figures opposite the blade in Fig. 223), but consider them as so many twelfths of an inch. Thus it is 12 twelfths, or one inch, for the square-cornered building, $8\frac{3}{4}$ twelfths for the pentagon, 7 twelfths for the hexagon, 5 twelfths for the octagon. The figures to use for other polygonal roofs are shown in Fig. 223, but the reader must bear in mind that the fractional part of the number becomes only that part of a twelfth on an inch. Thus, for the octagon the number is 4 23-24, which is lacking only 1-24 of a twelfth of an inch of being 5 inches. This is so near being 5 that we call it 5 twelfths of an inch for the amount to set off on the seat cut line as before described and shown in Fig. 226.

For a Triangular Building.—The backing line for a hip for a triangular building would be 21

twelfths or $1\frac{3}{4}$ inches to set off on the seat cut line, the latter being obtained by using 21 and 9 as compared with Figs. 225 and 226.

The backing of the hip is too often neglected. In fact, in most cases is not done at all, or if it is done, it is in a haphazard sort of a way. We have seen laborers (we will not say carpenters) take a hand-ax and hew off the corners of the hip, after it was set in place, at the time of putting on the sheathing boards. The valleys too should be backed and in most cases should be doubled on account of the downward thrust of the roof causing etxra weight on the valleys. However, it is not our intention to discuss construction in this work, but where the valleys are so doubled they should be backed one way only and that before spiking together. This makes a substantial valley and solid bearing for roof boards.

Tail End Cut of Hip or Valley.—This, too, is one of the neglected cuts, and carpenters generally pay no attention to it further than to leave the tail end long enough to catch the facia and then scribe the end cut to correspond with that of the common rafter.

In Fig. 227 we show this cut as at "A" and how it may be obtained with the steel square. From this, it will be seen that it is rather a difficult thing to get at, since the measurements are, so to speak, in another latitude. In all roofs there is an unseen, or co-pitch, and the end cut of the common rafter represents that pitch, and which, if cut square, will rest at 90 degrees from

the given pitch of the common rafter, and the cut in question must necessarily coincide with the unseen or co-pitch.

In Fig. 228 is shown the application of the

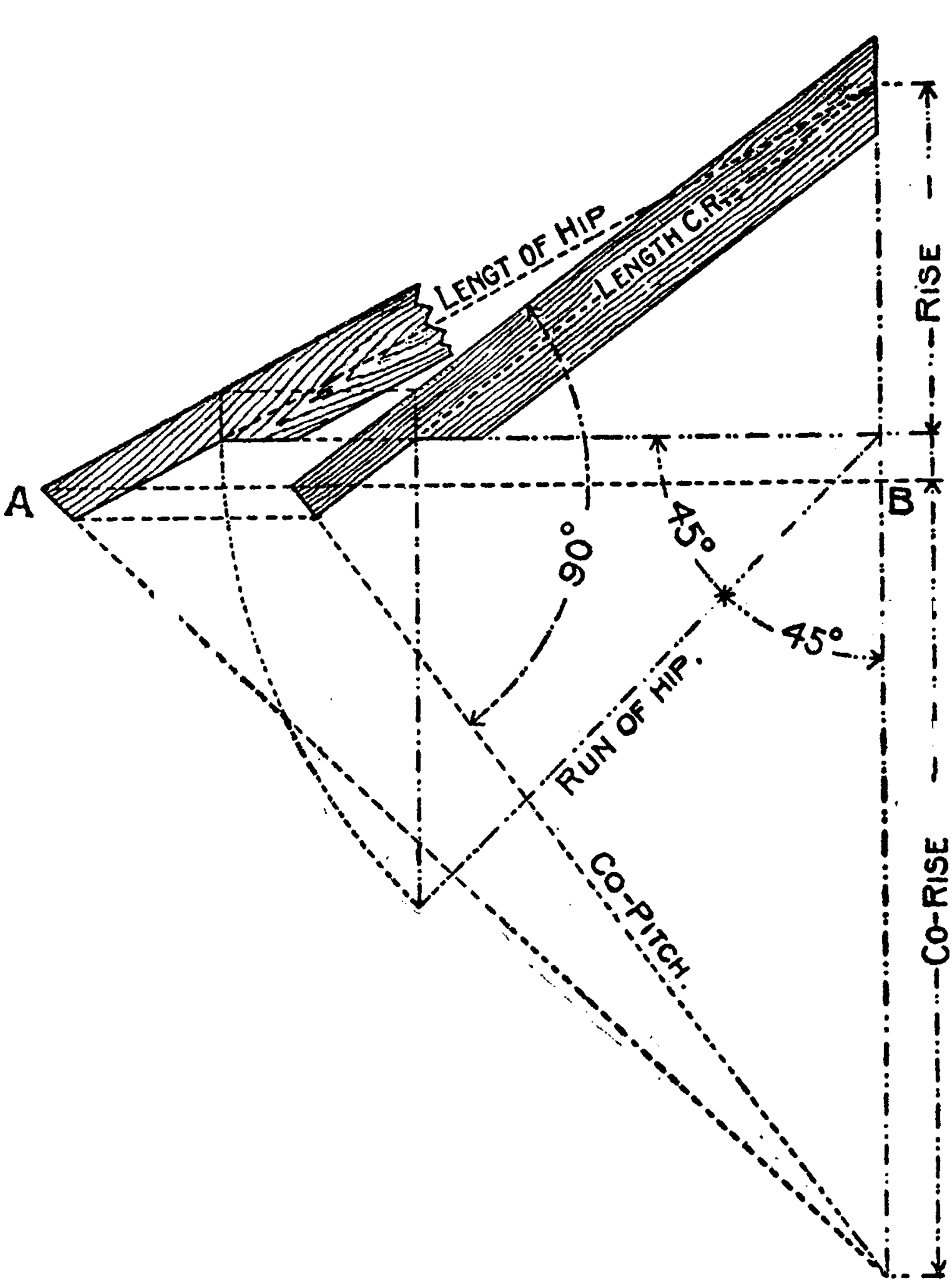

FIG. 227

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building. The dotted lines clearly show the angle that the tail end cut must bear to that of the common rafter.

There is no general rule, so far as we have been able to find, whereby this cut can be had

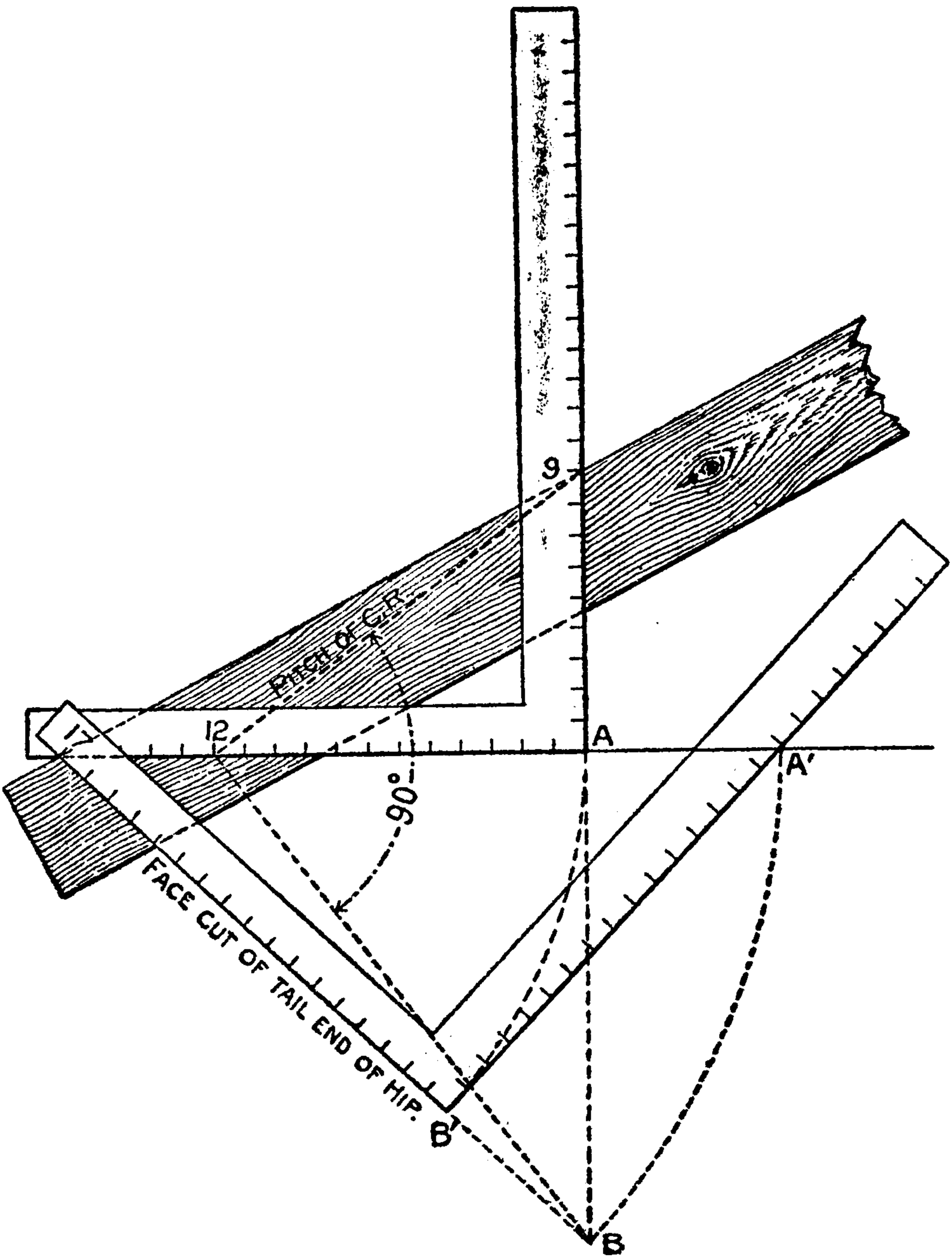

FIG. 229

direct from the edge of the rafter, as in other cuts, but it may be had by taking the run (17) on the tongue and the co-rise on the blade and applying this to a line parallel with the seat cut and the tongue will give the desired cut as shown in Fig. 229.

However, this is only the angle or where the cut would be at the center of rafter. To get the proper angle on the side of the rafter, the cut would pass through the point on the seat cut as before described for the backing lines.

The foregoing practically covers all of the cuts and bevels about the even pitch roof that may be readily obtained with the aid of the steel square. There are, of course, other ways of arriving at the same result by geometrical diagrams, etc., but there can be nothing better than a thorough knowledge of the tangents of the steel square and the relation that they bear to one another.

Side Cut of Jacks.—In Fig. 230 we show the side cut of the jacks from a 4 to 24-inch rise to the foot run and for polygonal corners from 4 to 12. In this illustration we show the figures to use on the steel square for twenty of the pitch lines and for the square corner and eight of the polygonal jacks, also for the level miter making in all 220 side cuts, or miters, that can be had from this illustration alone. Since the tangents of the polygons govern the figures to use on the tongue, they are as shown in connection with this illustration. Thus, to obtain the side cut of

the pentagon jack for the $\frac{3}{8}$-inch pitch, we use $8\frac{3}{4}$ on the tongue and 15 on the blade. The blade giving the cut.

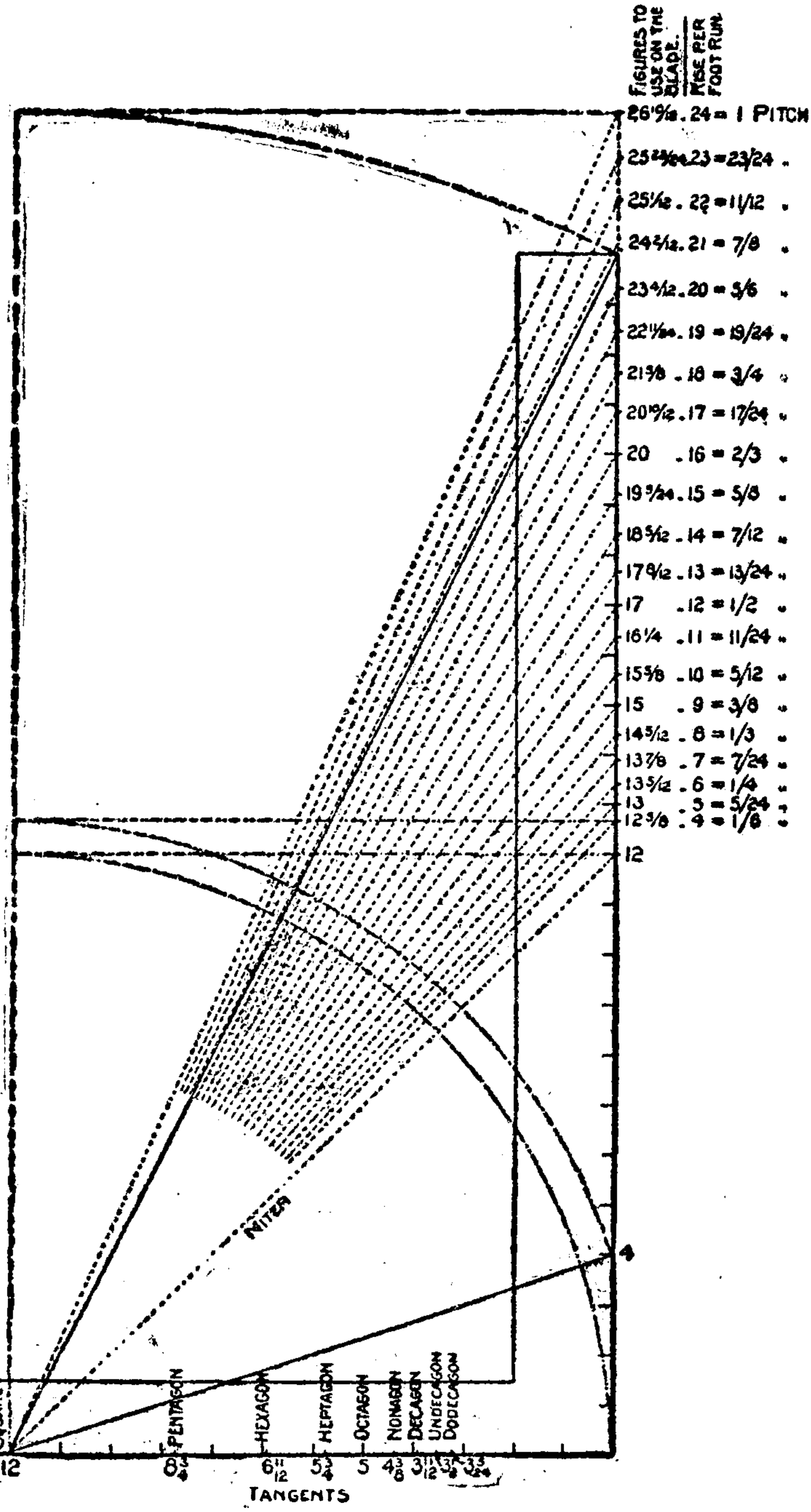

FIG. 230

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ing barn where he could have a level floor to lay off a diagram for a full size octagon template for the masons to work by, and yet these men thought they understood the square. They could frame the common hip and valley roof, but when they came to something a little out of the ordinary they did not understand the true principles involved. If these men had possessed a knowledge of the tangents and how to apply them on the steel square, they would have known in a minute's time what figures to use for all of the cuts, lengths and bevels required in the work.

We have seen the carpenter, after cutting and setting the common rafters, climb up the gable and scribe the sheathing boards to the pitch of the rafter instead of using the same figures on the square that he used for the seat and plumb cuts of the common rafter, and yet, he too in his mind knew all about the square and how to frame a roof.

If the first man had possessed a knowledge of the tangents, he would have multiplied the inscribed diameter of the hexagon by 6.93 (6 11-12) and reduced to feet and inches, would have given the length of the sides and all of the cuts and bevels for the roof. The second man should have multiplied his diameter by 4.97 and reduced to feet and inches, would have given the length of the sides of his template. It is the knowledge of such things as these that counts in the race for success, and the day is fast approaching when he

who would be successful in his trade must know the shortest and best methods.

Plumb Cut of Rafter.—In our rounds among the builders, we find that nine times out of ten the boss framer, after laying off the plumb cut

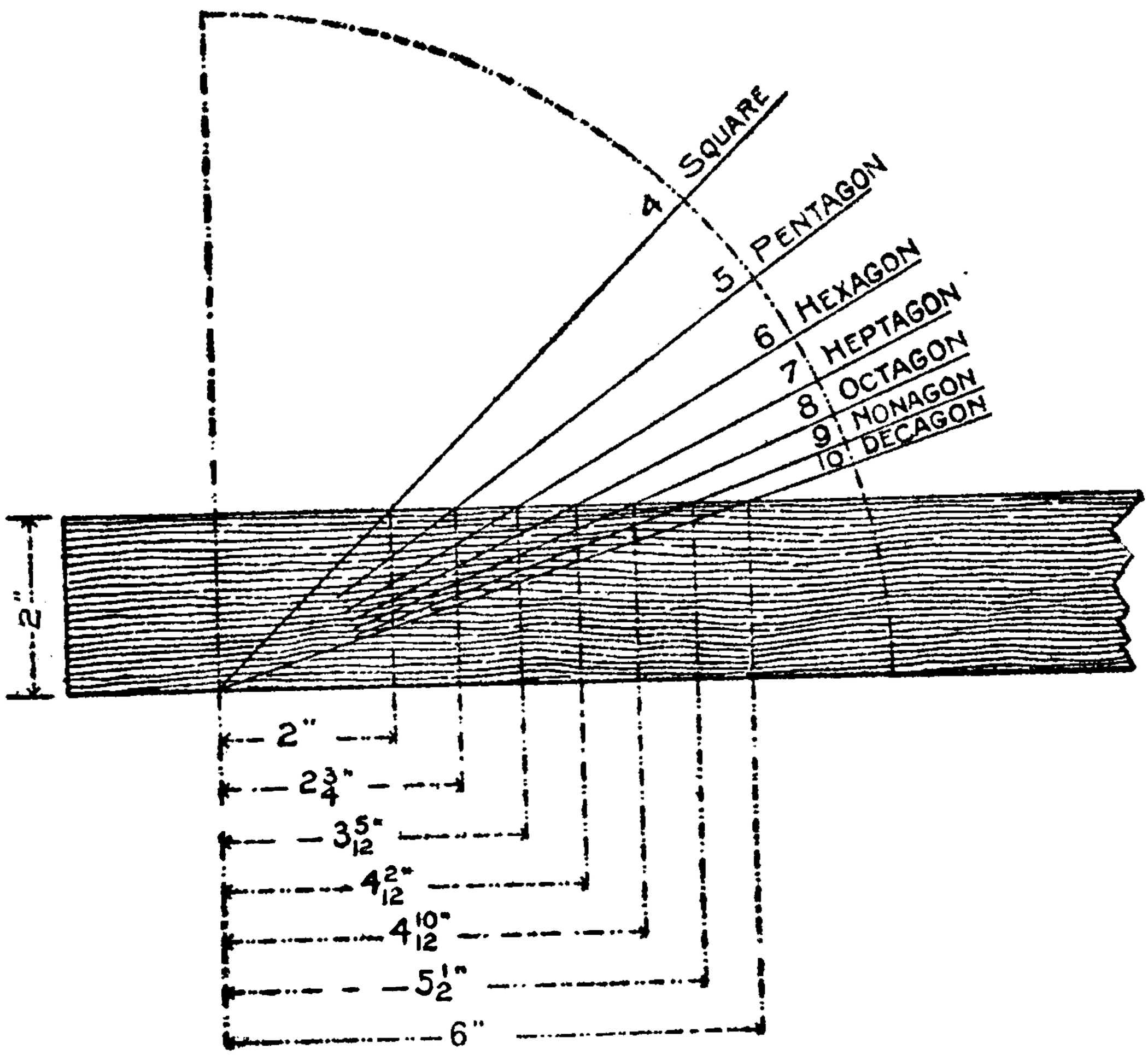

FIG. 231

on the rafter, would take a block cut from the rafter and place it edgewise along with the plumb cut and mark on the opposite side and then diagonally across the top of the rafter to the plumb line on the opposite side and then cut to these lines, which, of course, give correct results for either side cut of jack or hip for the square-

cornered building, but when asked to frame any other than for the square corner, more than likely could not explain and was, so to speak, up against it, because he did not understand the true principle. Yet what is true of the square corner is true of all other angles, which we think will be made clear by referring to Fig. 231. In this we show the angles for the polygons from 4 to 10 and are the same as those shown in Fig. 230, but the cuts are arrived at in a different way.

From this, it will be seen that it is the amount of the base of a triangle whose altitude is equal the thickness of the rafter, that is set off from the plumb cut. In the case of the square building, the base and altitude being equal is the reason that the thickness of the rafter set back from the plumb cut gives the proper angle across the top for the cut. In the illustration we show the amount to set off for the different polygonal jacks.

Octagon Jacks.—In Fig. 232 is shown the application for the octagon jack. The plumb lines A and B remain 4 10-12 inches apart, regardless of the pitch given the common rafter, as will be seen by referring to the elevation in connection with this figure. Here we have the $\frac{1}{2}$, $\frac{1}{4}$ and the level or no pitch. These lines represent the plumb cut on either side of the rafter and by cutting diagonally from one to the other across the back will fit to the side of the hip. It must be remembered that the thickness of the

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4 10-12 inches apart. But, after all, we do not get away from the use of the square, as will be seen by referring to the plan in Fig. 232. Here the square is shown applied to the back of the jack with the figures that give the octagon miter and the distance apart of the lines A and B is determined at the point where the blade intersects edges of the rafter, and lines drawn at right angles from these points from the rafter govern the distance apart the plumb lines will be. For any other polygonal jack, proceed in like manner, using the figures on the square that give their miter. The result, however, will be the same as given in Fig. 230, which is much the better system, because it gives the cut direct from the square. However, the formula given in Fig. 231 is worth knowing.

Side Cut of Hip.—In Fig. 233 is shown the companion piece to Fig. 230, and represents the side cut of the hip. A line from 12 to 12 on the blade and tongue represents the run of the hip and its length taken on the tongue and the length of the hip (from 17 to the desired rise on the blade) taken on the blade, will give the correct angle across the top of the unbacked hip. The blade giving the cut.

The first column of figures to the right of the blade represents the length of the hips from a 4 to a 24-inch rise in comparison with the common rafter and are the figures to use on the blade to obtain the side cut. The second column represents the rise in inches to the foot run of

the common rafter, and the third designates the pitch. Inasmuch as the lengths of the hip above the 16-inch rise exceed the length of the blade, it is necessary to reduce the scale. Therefore, the

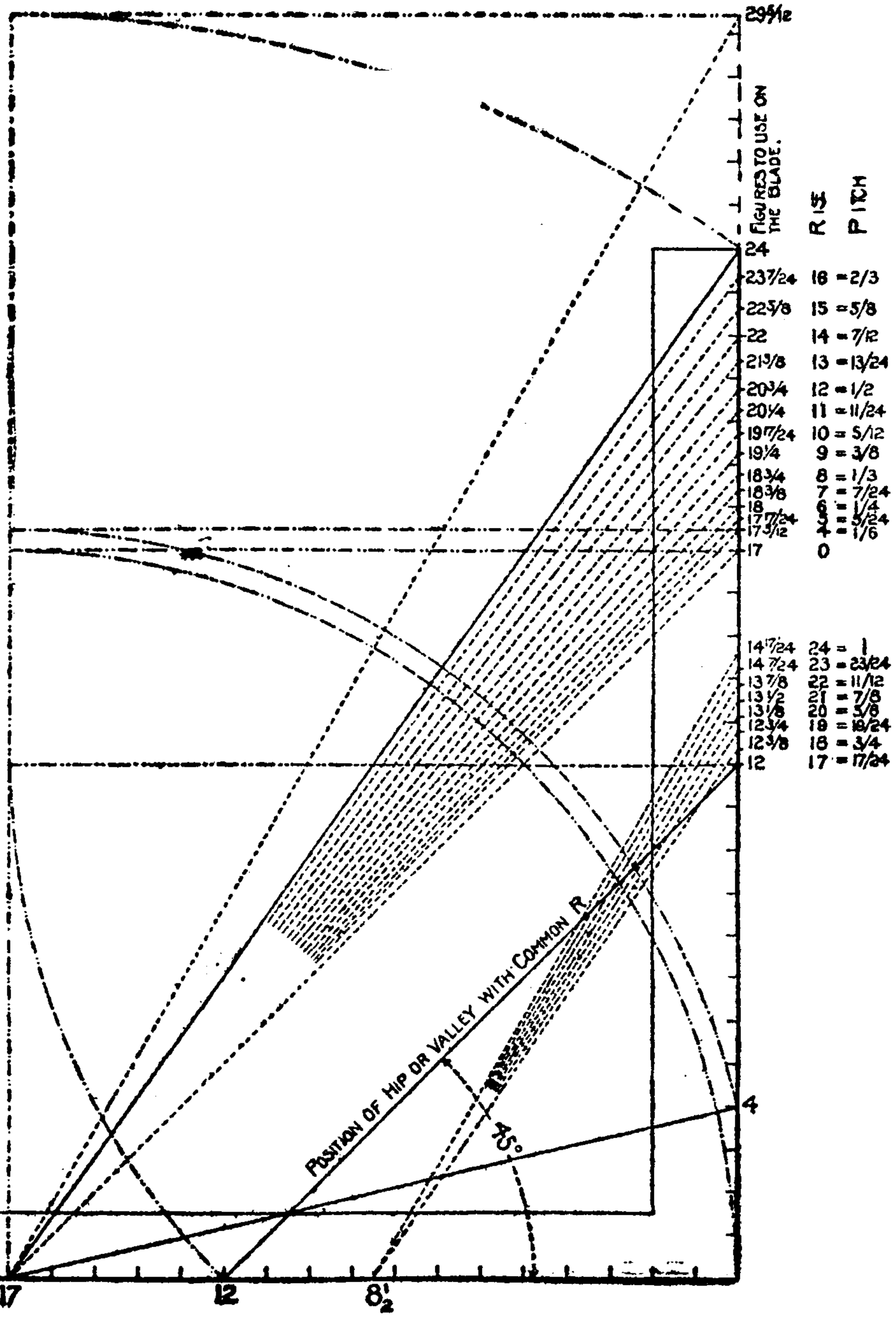

FIG. 233

lines centering at 8½ on the tongue are for the one-half scale. The figures to use on the blade are, therefore, reduced in like proportion to what they would have been in the full scale. However, it must be understood that any figures on the blade and tongue may be used that are in proportion to those used in the full scale. Every fractional mark on the blade represents a scale. Therefore, taking the side of the square that is divided in twelfths there would be $24 \times 12 = 288$ different scales and all giving the same result, but the intersections on the tongue would be in complicated fractions.

Lengths, Cuts and Bevels of Common Rafters.—In Fig. 234 is shown a part of a very convenient table for the length, cuts and bevels for the common rafter up to an 18-foot run and with a rise from 1 to 24 inches to the foot. We have only given the figures for two of the pitches (1-3 and 3-8).

The figures on the blade represent the rise to the foot run. The fractional figures to the left of the blade represent the pitch of the common rafter. The figures on the tongue represent the run in either feet or inches. Therefore, if we wish the length of the common rafter, for a 16-foot span for the ⅜ pitch, we take one-half of the 16 for the run on the tongue (8) and look in the square opposite ⅜ and we find 6 feet which represents the rise and 10 feet represents the length of the rafter. If it be an 8-inch run, then the figures found there would represent as many inches.

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difference. The length of the second jack will be that found in the second square, and that for the third will be found in the third square, etc. If the jacks are spaced on 24-inch centers then find the lengths in every other square. If they be placed on 16-inch centers, look under the 16th run and consider the length found there as inches. If they be placed on 18-inch centers, look under the 18th run, etc.

There are twelve scales in this table. Each figure in the run representing a scale and all giving the same cuts. Thus, the seat and plumb cuts for the common rafter are as follows:

Take the number of any run on the tongue and its rise found in the square above and opposite the desired pitch, on the blade will give the seat and plumb cuts. Take the number of any run on the tongue and the corresponding length of the rafter on the blade will give the side cut of the jack and also the face cut across the roof boards to fit in the valley or over the hip. The blade giving the cut on the former and the tongue in the latter.

Take the length of the rafter for any run on the blade and its rise on the tongue and the latter will give the miter cut across the edge of the roof boards, which is the same as the miter for the square hopper. The figures for the full scale are found in the twelfth run for the above cuts as before illustrated.

To Find the Side Cuts for the Polygonal Jacks.—Take the tangent on the tongue (see Fig. 230)

and the length of the common rafter found in the twelfth run on the blade and the latter will give the cut.

Lineal Board Measure.—This table also contains a complete lineal board measure for any width of board up to 18 inches, as follows:

Let the figures on the tongue represent the width of the board and those on the blade the length. The top figures in the intersecting squares opposite these numbers will be the contents of the board in feet and inches, as follows:

A board 6 inches wide and 9 feet long contains 4 feet 6 inches. A board 17 inches wide and 9 feet long contains 12 feet 9 inches. A board 15 inches wide and 8 feet long contains 10 feet, etc. A board 14 inches wide and 20 feet long, the answer would be found in the intersecting square opposite the starting points, as at X. Thus it will be seen that a completed table of this kind would come very handy as a ready reckoner. The reader will notice in the $\frac{3}{8}$ pitch that the lengths are without fractions. This occurs at three places on the blade—5, 9 and 16, respectively. Thus in the 1-3 pitch, the lengths end in fractions and are expressed in twelfths. For an 8-foot run the length would be 8 feet 7 5-12 inches. For an 8-inch run the 5-12 may be discarded as it represents less than half of a twelfth of an inch. The answer would then be 9 7-12 inches.

Length of Rafters for Odd Runs.—We wish to call special attention to the table at Fig. 234, in

the convenience of same for finding the lengths of rafters for odd runs, such as feet, inches and fractions of an inch in the run, as the figures stand for either feet, inches or fractions of an inch. The fractions being expressed in the same denominations (twelfths), permits of a sliding scale, as follows: for an example, suppose the run is six feet and one-half inches with a one-third pitch. In the intersecting square opposite the rise and run, we find seven feet two and six twelfths which answers for the six feet. For the six inches in the run, read the above figures as so many inches and twelfths of an inch, and for the half-inch, read the above figures again as so many twelfths and fractions of a twelfth of an inch. The whole may be expressed thus:

For the six feet . . 7 feet 2 and 6-12 inches
For the six inches . . . . . 7 and 2-12 inches
For the six-twelfths . . . . . 7-12 inches

Answer . . . . . 7 feet 10 and 3-12 inches

Then 7 feet 10 3-12 inches is the correct length. The last two figures (8 and 6) are dropped because they represent too small a denomination to be retained. Remember these figures represent twelfths (not tenths) and we only carry to the next column when the sum exceeds twelve, otherwise the operation is just the same as in simple addition. If the run was, say 5 feet 7 and 9-12 of an inch, the figures would be expressed thus:

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shown at No. 1, as follows: From the run of the common rafter, erect the desired rise as at A-D

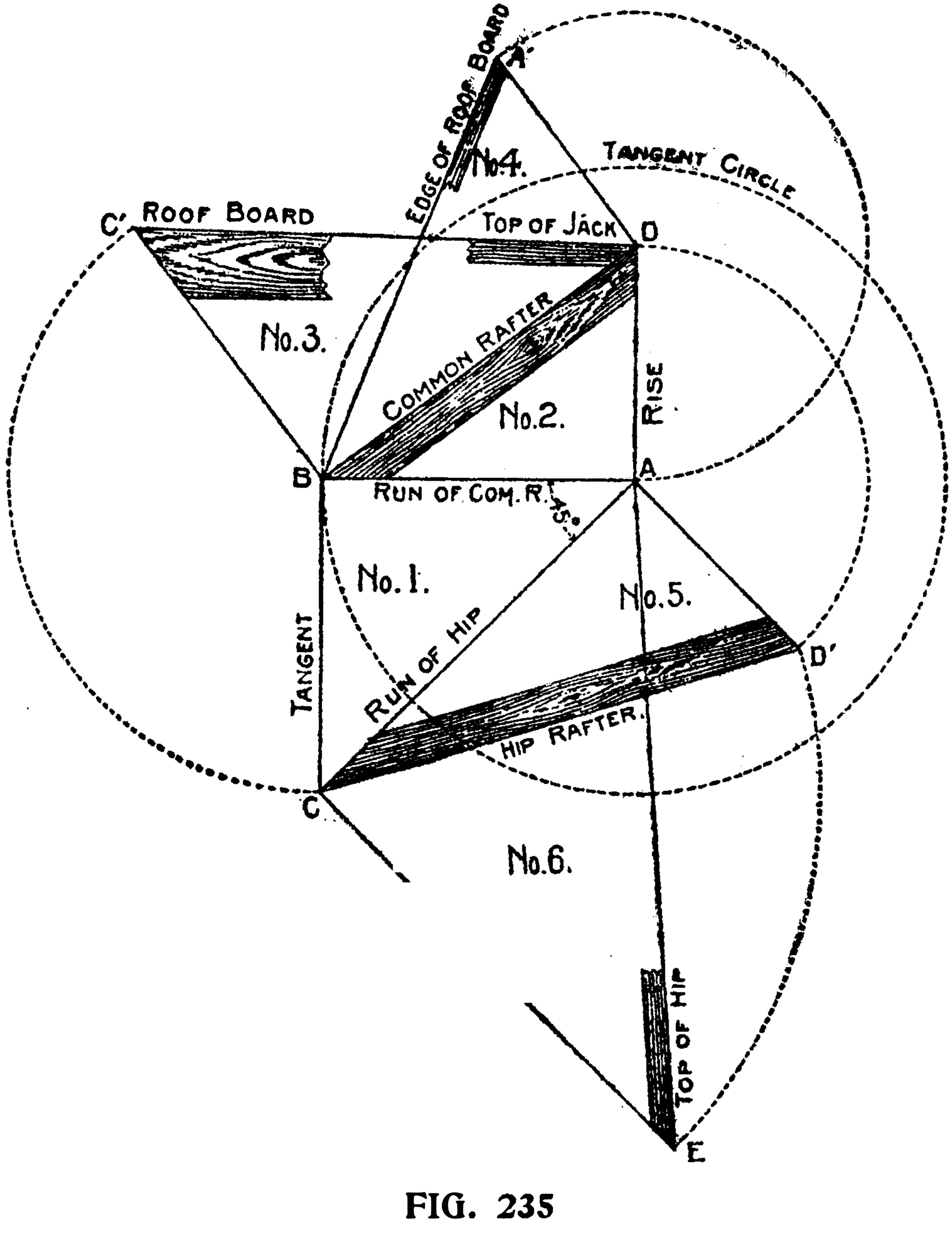

FIG. 235

and connect D-B. This forms the second triangle and contains the length, seat and plumb cuts of the common rafter, as shown in No. 2. At right

angles from the common rafter draw a line equal to the tangent as B-C[1] and connect D-C[1]. This forms the third triangle, as shown in No. 3. In this are shown the face cut of the roof boards to fit in the valley or over the hip. This angle also gives the cut across the back of the jack to fit against the hip or valley, commonly called side cut of the jack. At right angles from the common rafter draw a line equal to the rise as D-A[1] and connect B-A[1]. This forms the fourth triangle, as shown in No. 4. In this is shown the edge or miter cut of the roof boards to fit in the valley or over the hip. In other words, this is the same as the miter for a hopper. Now then, we will work from the other side of triangle No. 1. From the run of the hip draw a line at right angles from A-C equal to the rise, as at A-D[1] and connect C-D[1]. This forms triangle No. 5, and contains the length, seat and plumb cuts of the hip. From hip rafter and at right angles to A-C draw a line equal to C-D[1] as C-E and connect A-E. This forms triangle No. 6 and in it is contained the top or, commonly called, the side cut of the hip. The illustration is for the 3-8 pitch or 9 inches rise to one foot run of the common rafter. For an octagon roof the angle at No. 1 would be $22\frac{1}{2}$ degrees. For a hexagon roof it would be at 30 degrees.

In Fig. 236 are shown all of the above angles formed by as many steel squares, with the corresponding numbers placed on same that help to form two of the sides of each angle, and, by referring to the preceding illustration, the reader can

readily see how the cuts are obtained on the steel square.

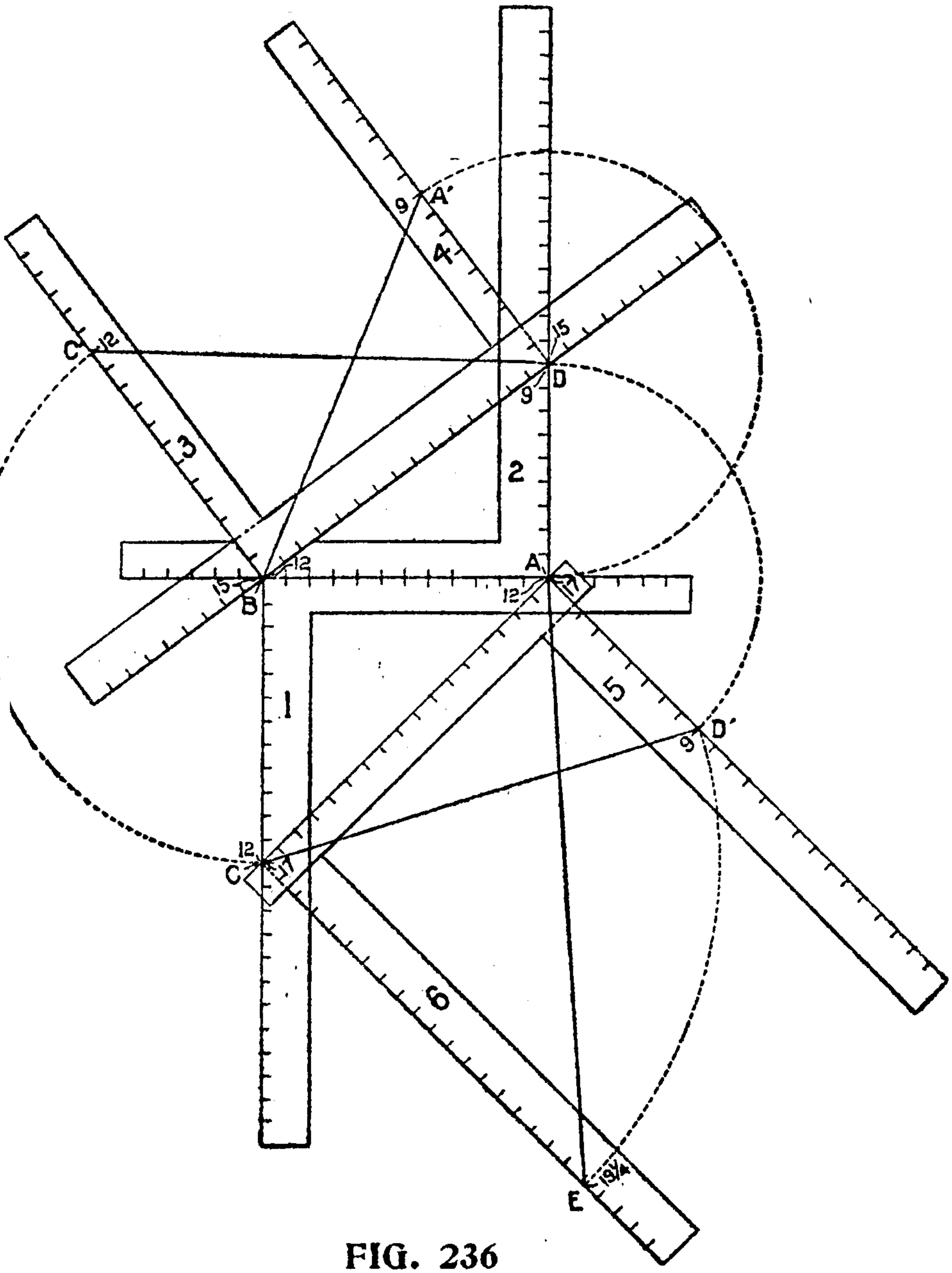

FIG. 236

Developing Cuts and Bevels.—Illustrating the cuts and bevels with the triangle is probably the most practical way of showing the various cuts

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In Fig. 237 are shown the triangles for a hexagon (six sided) roof and by comparing with the preceding illustrations, the reader can see wherein they differ. The application is the same except in the sixth angle. Angle No. 1 represents the plan and governs the layout of the diagram. In

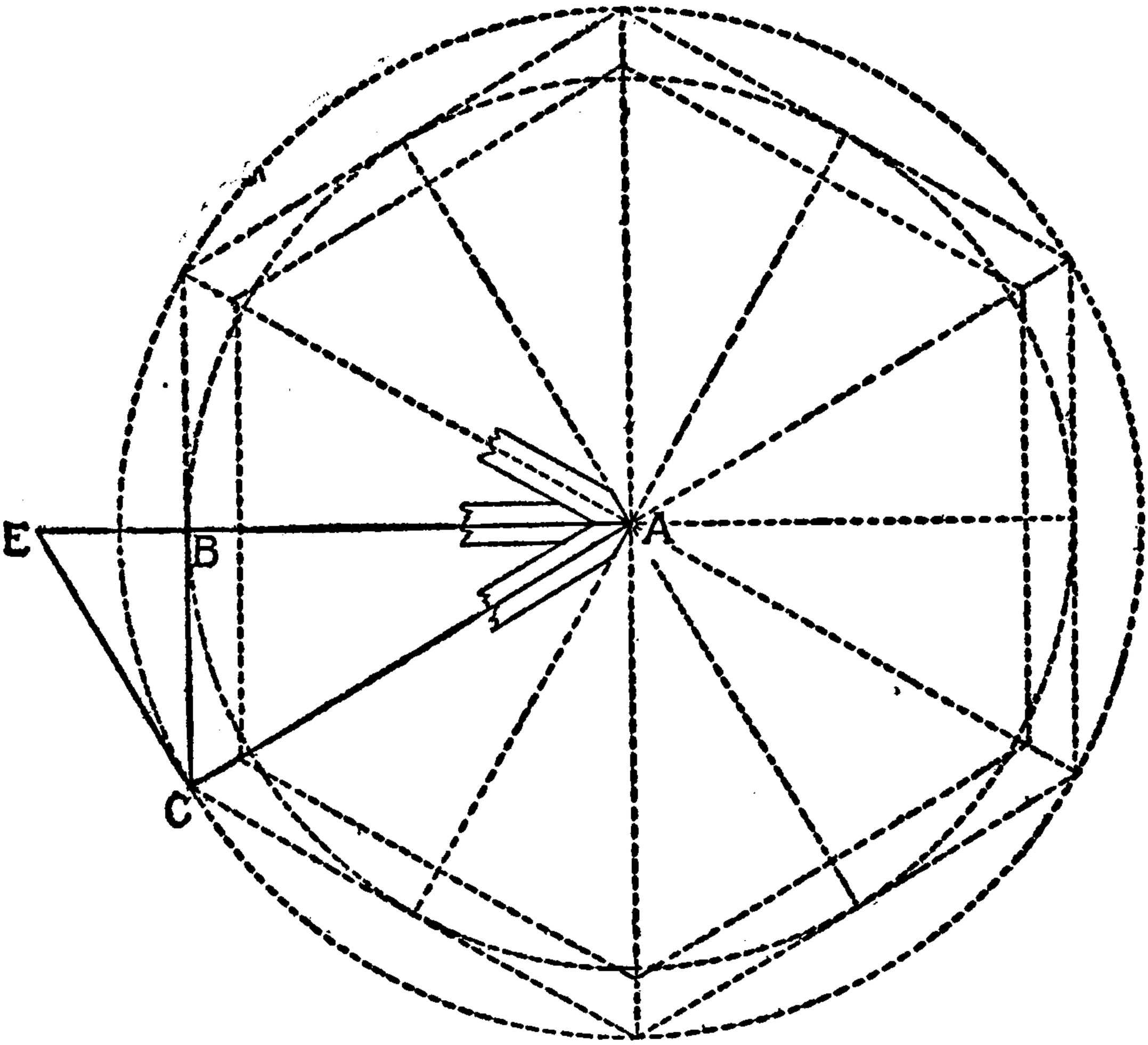

FIG. 238

this, the angle between the runs of the common rafter and the hip is at 30 degrees. Now, by referring to Fig. 238, we show the angle bounded by A-B-C as shown at No. 1 applied to the plan of the roof as follows:

A-B run of the common rafter. A-C run of

the hip. B-C tangent of the common rafter. Now by extending A-B intersecting a line at right angles from A-C as at E, then E-C will represent the length of the tangent from the hip. Note:—See the difference in length when compared with the run of the hip.

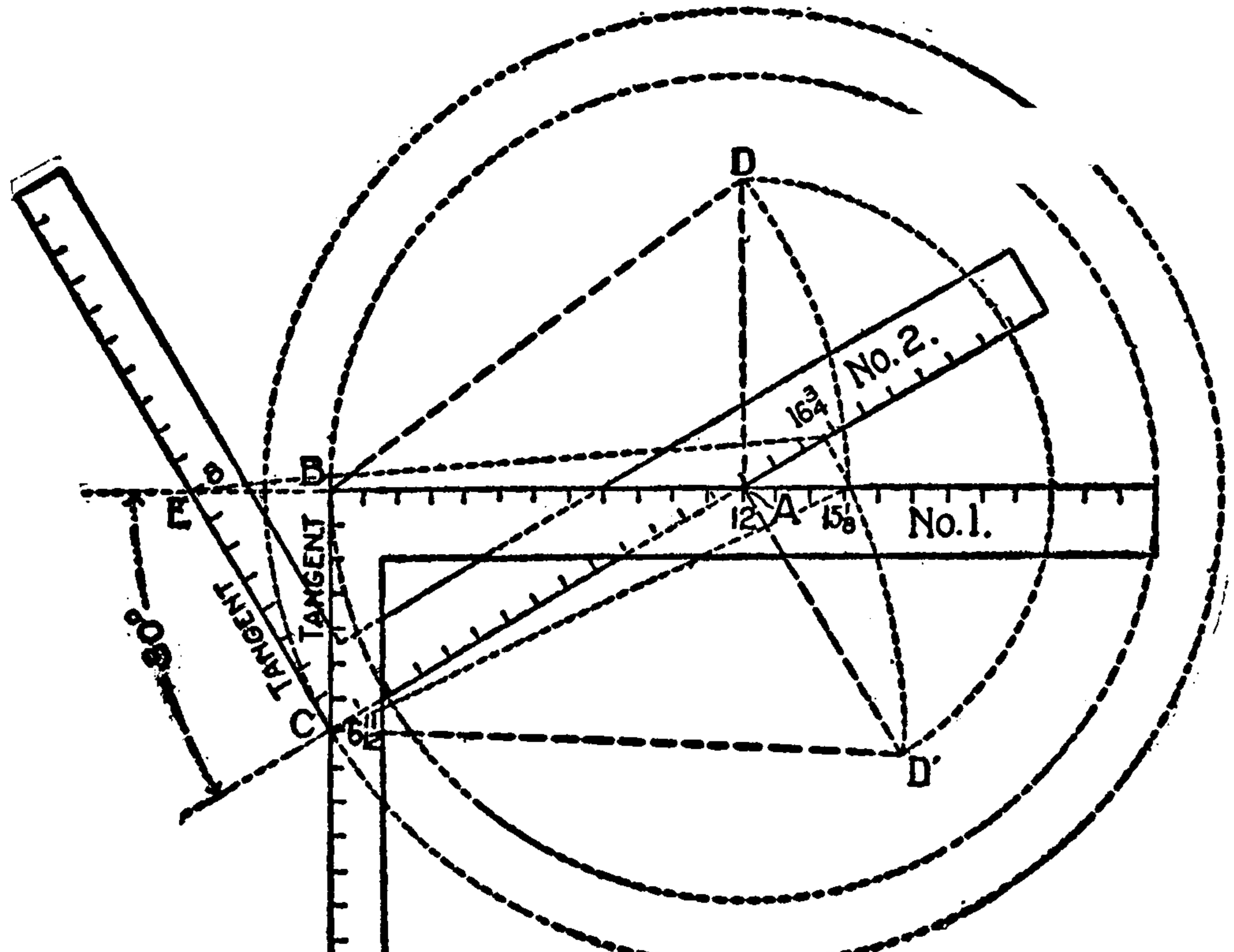

FIG. 239

In Fig. 239 is shown how these angles may be obtained with the aid of two steel squares. It may be worked to a scale of one inch to the foot, or full scale for a one-foot run of the common rafter, as shown in the illustration. The figure on the tongue that gives the hexagon miter

(6 11-12) represents the tangent for the common rafter as shown on square No. 1, and by placing square No. 2 with its heel resting at 6 11-12 and with the blade intersecting at 12 on square No. 1, then a line continued from the heel of square No. 1 and in line with the blade intersecting the tongue of square No. 2, which in this case is at 8 and represents the tangent for the hip. Now by erecting the rise from the intersection of the blades to D and D′, then B-D represents the length of the common rafter and D′-C that of the hip and these lengths, taken on the blade of the respective squares, will give the figures to use for the side cuts of the rafters. Thus—6 11-12 and 15 1-8 as shown, will give the side cut of the jack, or of the common rafter, to fit in the angle between the hips at the peak (see Fig. 238) and 8 and 16 3-4 will give the side cut of the unbacked hip to fit in the peak, or if it is first backed, then the same figures as shown on square No. 1 applied to the backing plane will give the same result. But, of course, this is not practical because the ends of the hip would run to a feather edge, as shown. A better way is to insert a hexagon block with sides equal the width of the hip, then the cut of th· hip would simply be the plumb cut. This would afford a better nailing space and each hip would hav· a direct bearing against the one on the opposite side.

Seat and Plumi Cuts.—In Figs. 230 and 231 are illustrated the side cuts of polygonal jacks and tc complete this linc ot work, we show in

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12-inch mark on the tongue resting at the rise, locates the angle of the respective runs with that of the common rafter and the figures to use on the blade of the square are the same as those used for the polygonal miters and as shown in the table. It will be seen, the vertical line dropping from 12 on the tongue of the steel square at the seat cut of the common rafter, as at B, and where the same intersects the figures on the tongue of the squares resting just beneath on the individual runs, gives the figures to use on that member for the cuts. The rise being the same as the common rafter, we use the same figures on the blade, as will be seen by referring to the illustration. Now if the runs of the hip were pivoted at the point of the rise, as at A, and we could raise them up until they rest on the horizontal line, it would be found that the pitch lines would center at one point at the top, as at D, and they would all fall in between 12 and 17 on the tongue and center at 9 on the blade. The figures on the tongues of the squares would remain as shown for the seat cut. If there was no pitch given to these rafters, then the corresponding figures that give the polygonal miters would give the side cut of the hip, though the cuts on the square would be reversed.

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