ROOF FRAMING

MADE EASY

A PRACTICAL AND EASILY COMPREHENDED SYSTEM, ADAPTED TO MODERN CONSTRUCTION, FOR LAYING OUT AND FRAMING ROOFS

THE METHODS ARE MADE CLEAR AND INTELLIGIBLE BY

NEARLY 100 ENGRAVINGS

WITH EXTENSIVE EXPLANATORY TEXT

BY

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Second Edition, Revised and Greatly Enlarged

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PREFACE.

In placing this, the second Edition of this little work before the student of Architecture or Building construction I would state that the rapid sale which the previous edition has had, warrants the assumption that this will also be appreciated by those who are desirous of becoming proficient in the higher branches, and who wish to apply the best and simplest methods in practice. With the assurance to the student that the contents, if studied, will return him full remuneration by his becoming more valuable on account of his increased knowledge; I send it forth confidently.

The articles were originally published in "Carpentry and Building" and "The Carpenter" and are now republished, by permission, edited and revised.

The entire work is dedicated to my Wife, through whose aid and encouragement I have been enabled to persevere and succeed in the study of technical principles.

The Author.

New York City, 1903.

ROOF FRAMING MADE EASY.

CHAPTER I.

The Principle of the Roof and General Directions.

With a view of explaining the principle of the truss and its practical application in the construction of roofs and bridges, I have commenced with this chapter.

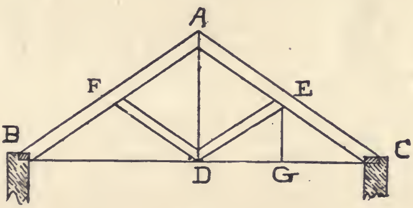

Fig. 1.

Let A B and A C be two rafters resting together at the ridge or point, as A. Even by their own weight, these two rafters would have a tendency to slip at the points B and C, and to sink at A. If a tie rod or beam be stretched from B to C, and the rafters, A B and B C, be made stiff or rigid, and the tie, B C, not liable to stretch, then A will be made a fixed point. This is the ordinary roof of two rafters in which the tie, B C, is the attic floor beams, and which form may be used for houses of small span.

When the span is wide, so wide in fact that the tie, B C, being unsupported in the centre, tends to sag by reason of its length, then the conditions of stability are injured. Now if from the point or peak A a string or tie be let down and attached to the middle of B C, as D, it will then be impossible for B C to bend or sag down, as long as A B and B C are the same length. D will be also like a stationary point if the suspension or tie A D be of iron or wood and not stretch. But the span may be increased, or the size of the rafters A B and A C diminished until the rafters tend to sag, and to prevent this, "struts," as D E and D F, are set in, reaching from the stationary point D to the middle of each rafter, or to the centre of its length, as E and F; thus making E and F stationary points, provided the struts E D and F D remain their full length.

By this means they "truss" or tie up, the point D, and the frame, A B D C, is a trussed frame, or in the term applied in carpentry, a "truss." Similarly, if D C be long its centre can be suspended from the fixed point E by a suspension rod, as E G.

In every truss there are two principal strains exerted on the members. These are termed *Compression* and *Tension.* For this simple truss the rafters A B and A C are in *Compression,* or being pushed together. A D and B C are extended, or in *Tension.* Those which are in tension can either be made of wood (as wood is not liable to stretch) or of wrought iron rods, but never of ropes, or any material likely to stretch easily.

From the above, the student will understand that: the rafters, by their not being subject to compression or crushing, and the tie rod or beam, not being liable to stretch, or, in better words, subject to tension, and the suspension rod complete the truss, thus preventing the sagging of the centre of the tie beam.

In modern roof construction, engineers, as a rule, use timber for rafters and struts and iron for tie and suspension rods; these materials being light and easily put together; and I am sure many readers will meet roofs of this class.

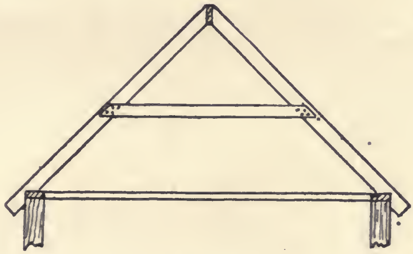

Fig. 2.

In the ordinary form of house roof shown at Fig. 2, the rafters are in *compression*, the ties, or attic floor beams, in *tension*, and the collar beam is in compression, as it takes the place of the struts, yet gives the head room.

GENERAL DIRECTIONS.

Roofs should be laid out to a scale on a large sheet of detail paper or on a drawing-board, using a lead pencil and two-foot rule or steel square. The writer generally uses either 3 inch or 1½ inch scale; if possible, as it sometimes is on small work, full size.

The reason these are the best working scales is because the *three inch scale* works as follows:

3 inches	= 1 foot	1/4 inch	= 1 inch
1 1/2 "	= 6 inches	1/8 "	= 1/2 "
1 "	= 4 "	1/16 "	= 1/4 "
1/2 "	= 2 "	1/32 "	= 1/8 "

The *one and a half* inch scale is similar but the divisions are not so handy. For instance:

1 1/2 inches	= 1 foot	1/8 inch	= 1 inch
3/4 "	= 6 inches	1/16 "	= 1/2 "
1/2 "	= 4 "	1/32 "	= 1/4 "
1/4 "	= 2 "		

The above two scales are the usual working scales with the exception of the half size proportion which is very simple and easily applied thus:

6 inches	= 1 foot	1/2 inch	= 1 inch
5 "	= 10 inches	1/4 "	= 1/2 "
4 "	= 8 "	1/8 "	= 1/4 "
3 "	= 6 "	1/16 "	= 1/8 "
2 "	= 4 "	1/32 "	= 1/16 "
1 "	= 2 "		

The foregoing scales are the best for mechanics, either foremen or at the works. The full size laying out is best when possible. Whether the work is laid out to scale or full size, the exact measurements should always be marked in plain figures on every piece.

The figures on the steel square for marking cuts may be used if desired, by placing the square on the scale drawing and noting the figures on the blade and tongue.

CHAPTER II.

Laying out and Framing a Simple Roof.

Let A B C D Fig. 3, be the plan of the wall plates. A D a gabled end, and B C a hipped end of the building. The roof is 12 feet wide to the outside faces of

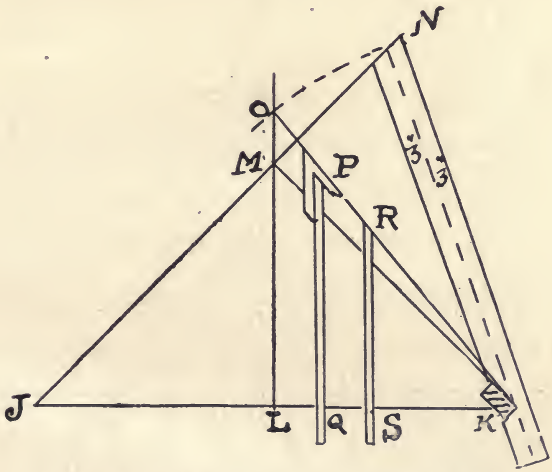

Fig. 4.—PLAN AND LAYOUT OF A SIMPLE ROOF.

the wall, and the rise or *pitch* 4 feet or one-third the span. The dotted lines denote centre lines.

To lay out the gable end produce the center line of the ridge E I F to G and from F measure up 4 feet, join G A and G D. Now set off on each side of the dotted

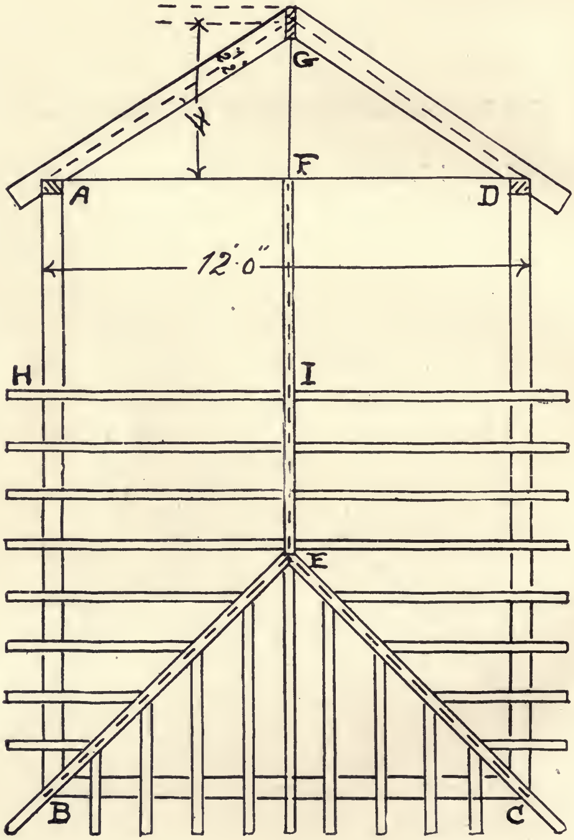

Fig 3.—PLAN OF RAFTERS.

line shown, the width of the rafter 2 inches on each side for a 4 inch rafter, and 3 inches on each side for a 6 inch rafter as shown on the top of Fig. 3, deduct half the thickness of the ridge, half inch, from each rafter peak, cut also notch out for the cut on the plate. All the rafters from F to E will be framed thus:

For the hip rafters, take the distance B C and transfer it to J K, Fig. 4, divide it into two parts 6 feet at L, and square up as L M O. Join M J and M K. Produce J M to N, and join N K. N K, will be the centre line length of the hip, and the width may now be set off on each side of it in the manner shown in the diagram.

With K as centre and K N as radius, strike the arc N O, cutting L M extended in O. On L K lay off the jack rafters as Q P S R, etc.; equally spaced and square to the wall plate. The exact lengths of the jacks will be to the line O P R K, and their side bevel will be as at P. The bottom notch will of course be as at A or D; K shows the bottom notch for the hip rafters and N the peak cut or plumb cut. Great care should be taken to have the lines as accurate as possible, so that the measurements will be exact.

CHAPTER III.

Hip and Valley Roofs.

The next roof which I produce is one of the hip and valley class, or a main rectangular building, with an L or addition. A B C F D E, Fig. 5, is the plan of the building and the outside line of the wall plates. The roof is of half pitch or square pitch as some mechanics call it, which means that the height of the roof is equal to half the width of the house. The house has two gables, one on each end of the main part with a hip on the L, and the intersection of the L roof with the main

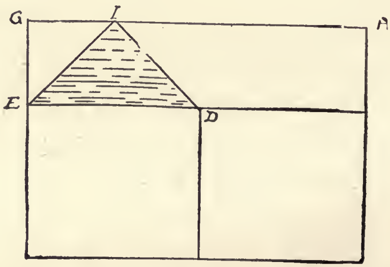

Fig. 6.

roof produces two valleys. E I D is the plan of the hip and E I D, is the elevation of it shown on the elevation Fig. 6, where the general view of the constructed roof is shown. Q J, and J F, (Fig 5), are the valleys on the plan.

In framing this roof the simplest way is as follows: To obtain lengths and bevels of the common rafter, produce the ridge line G J H to L and K. Join A K, and K Q; also B L, and L C. A K, will be the neat length of the common rafter, if no ridge board is inserted; but if there be a ridge board, half its thickness must be sawn off the length on the bevel. K is the bevel for the top or peak cut and A, the bevel for the cut on the plate. Any ordinary mind will see the simplicity of this method.

For the hip rafters which will stand over the seats E I, and D I, produce the line D I, to M, and set off on it the height of the pitch I M, equal to K G. Join M E; M E will be the exact length of the hip rafter required, and the bevel at M will fit the top cut, and that at E the plate cut. In regard to the cuts for the jack rafters, which run up the hips and valleys, it might be said that the top cuts against the ridges for the rafters which run up the valleys have the *top cut* the same as the common rafter top cut. The bottom one which nails against it, can be readily determined by the following simple method: Produce the ridge line J I, to N, and make D N, and N E, equal to M E, the length of the hip. W is the jack on its seat or as it will appear in position. X is the exact length of it from the plate line to the hip, and the bevel at X will be the exact bevel for all jacks both on hips and valleys; being reversed for different sides, right and left hand.

The plumb cut of the jacks will be half pitch, or on the steel square, 12 and 12.

In order to prove the exactness of this method of

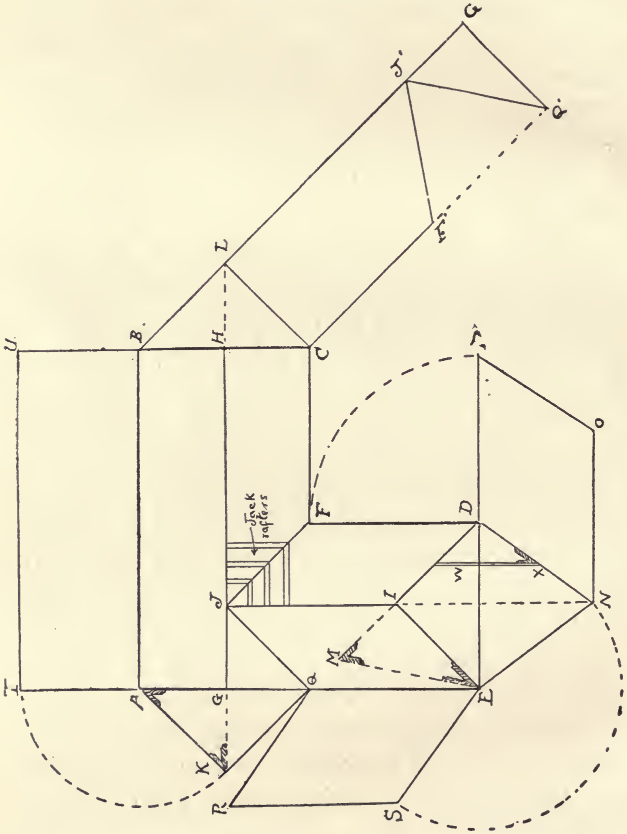

Fig. 5.

laying out such a roof, we will proceed to develop its planes or sides.

As to the rectangular plane, A B G H, take a pair of compasses with a pencil point, and with A, as centre, and with A K, as a radius, describe the arc K I; draw T U, parallel to A B, produce G A, to T, and H B to U, this will give A B U T, the exact covering of A G H B, on the pitch A K; A K, being the length of the common rafter with its necessary bevels.

For the plane J H C F, produce B L to G′, and draw C F Q parallel to B L J G′. Make L J G′ equal to H J G, C F equal to C, F, also F′, Q′, equal to Q, F, make J, F, and J, Q, on the right, equal to M, E, which will complete the plane and surface to cover G J H C, F Q on the plan.

For the plane J F D I, take D as centre, and with D F as a radius describe the quarter circle F P. Produce E D, to P, and through P draw P O, parallel to D N, also through N draw N O, parallel to D P. D N O P, will be the developed covering, and Q R S E is similarly found.

B L C and A K Q are the gables.

Now if this roof be laid out on a piece of thin wood or stiff Bristol board the roof can be folded over by cutting entirely through the following lines: Cut from K to A, A to I, I to U, U to B, B to L, L toG′, Q′ to J′, J′ to F′, F to C, C to F, F to D, D to P, P to O, O to N, N to E, E to S, S to R, and R to Q. Also make a slit half way through the thickness of the board, from Q to A, A to B, B to C, C to L, D to N, D to E, and E to Q. By folding the sides or planes over, the exact roof will be seen, thereby proving the correctness of the method.

The many apparently complex roofs which are nowadays placed on frame buildings are apt to discourage those young mechanics who are ambitious, so in order to simplify and bring them within the grasp of all I have now adopted a plan of roof of somewhat unusual form.

At Fig. 7 the plan is A B C D E F G H I J L and K, being the plan of a small frame house costing about $2,000. Fig. 8 is an end view or gable elevation showing the pitch of the common rafters which we will as-

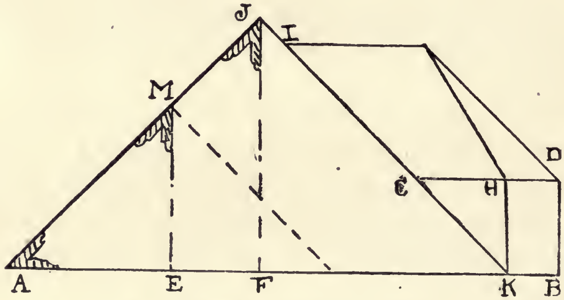

Fig. 8.—PROJECTION OF ROOF.

sume to be full pitch, or 12 inches rise and 12 inches run on the steel square. A B is the top line of the plate across the bay, or across the widest part of the house. A K is the span across the main walls and E J the rise or pitch; therefore A J will be the length of the common rafters on the plan Fig. 7, that will be set on the plate A K from N to O on the ridge. A G, Fig. 8, is the span across the narrowest part of the house or from A to B, Fig. 7, and E M is the rise or pitch, conse-

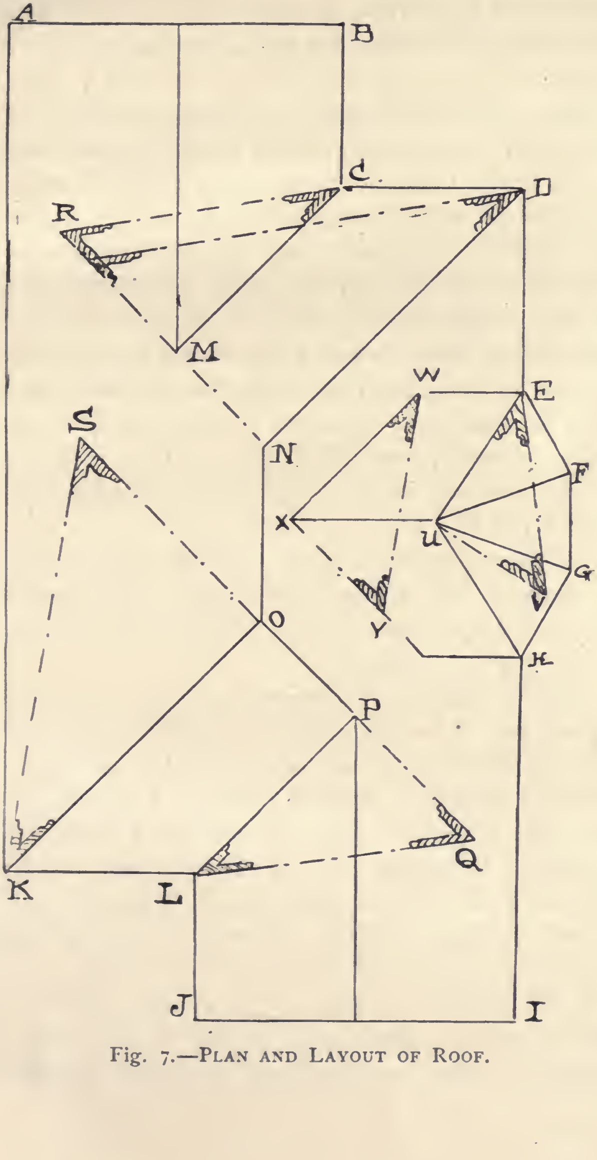

Fig. 7.—Plan and Layout of Roof.

quently A M will be the length of the short common rafters and the bevels will be as represented at J M and A.

Now to find the lengths of the hips and valleys and bay window rafters, refer to Fig. 7, and commencing at the near valley C M square up the line M R, make it equal to E M on Fig. 7 and join C R. C R will be the length of the valley with top and bottom bevels as shown. On the seat of the hips N D, square up the rise N T equal to E J, Fig. 7, and join D T for length of hip, with top and plate bevels as at D and T. It will be noticed that these rafters are parallel on the lay-out because their seats are parallel, therefore they must be correct; the valley rafter L Q to stand over L P is determined in like manner also the hip S K to stand over O K.

As I have previously shown several ways to obtain the lengths of jack rafters on half pitch roofs I will not repeat this simple method here but go on and give lay-out of bay window timbers.

Referring again to the engraving Fig. 8 we find that the plate line of the bay C H D is higher or raised up 4 feet above the level of the plate line of the principal or main walls as A G B; to find lengths of rafters we go back again to Fig. 7. Here on the seat of the hip E U we proceed to square up the rise U V and join E V, which will be the length of the hip U V, being equal to the rise C J, Fig. 8. There will be four hips this length to stand over E U, F U, G U, and H U, on the seat of the W X. Square up the rise X Y and join W Y for length of valley. There will be two needed, one for each side. Jacks can be found as before described.

Regarding the jack rafters reaching from the valleys over W X to the hips D N and O P I might state that the bottom and top cuts will be alike up to the points N and O where the hips join the ridge N O. Against it they will be a square cut on top edge with the down cut as at J Fig. 7.

When calculating the timbers or laying out roofs of this description, too much care cannot be bestowed in finding the exact number of rafters required, the right and left hand cuts of the bevels on the jacks, etc., and the exactness of framing to the neat lengths required so as to prevent mistakes or recutting.

CHAPTER IV.

Roofs of Irregular Plan.

This chapter embraces a roof of another and rather uncommon plan, and one which will be interesting to work out. It is a form of roof which sometimes occurs and will prove useful.

A B C D, Fig. 9, is the plan, and it will be noticed that the side walls are not parallel, or at equal distance apart from end to end, but spread or widen out from A to B, and from C to D, or B D is longer than A C. Similarly A B, is longer than C D, and not parallel to C D. For this reason coupled with the necessity of keeping the ridge level on both sides a deck is formed on the top, or more properly two ridges are needed, one for each side, and parallel to each wall plate; these are shown at E F and E G.

The seats of the hips as A E, C E, B F and D G, are found by bisecting each of the separate angles on the plan, which can be done by taking any two points equidistant from the apex of the angle as A, and striking intersecting arcs. (As every student knows how to do this I will not illustrate it here.) This process will give the seats of the hips as shown and lettered, with the addition of a short piece of ridge F G.

To find the lengths and bevels of the rafters, proceed as follows:—For the common rafters to range from U E, to V F, on the one side, and from E W, to G X,

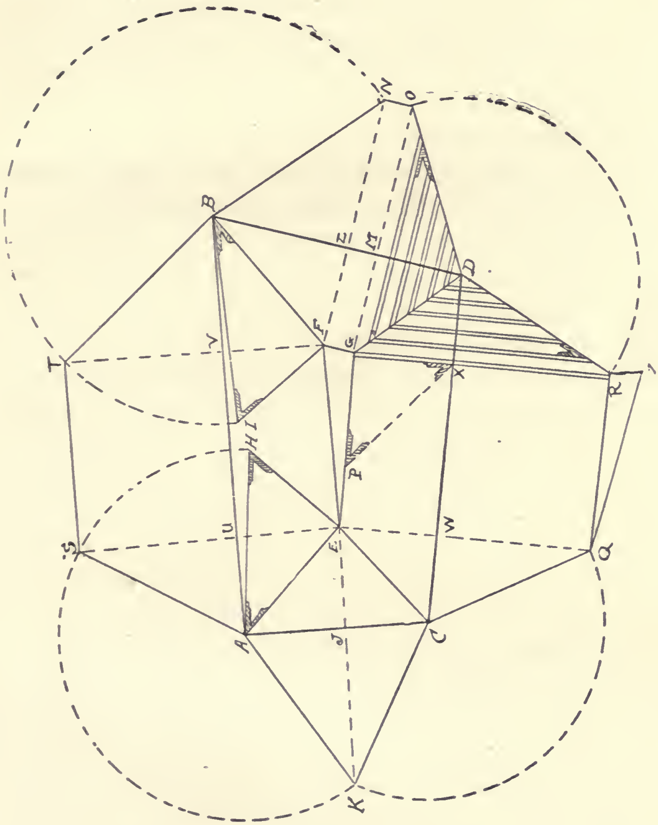

Fig. 9.

on the other side; raise up the pitch G P. Square out from G to X, and join P X which joining line will be the exact length of the common rafter from outer edge of plate to centre line of ridge. To obtain length of hip rafters square up from each point at the peaks, as E H; F I, on one side. Make E H, and F I each equal to G P, A H, and B I will be the lengths of the hip rafters, which will rise over A E and B F. The hip rafters which will be set up over the seats, C E, and D G, are determined in a similar manner. The top and bottom bevels delineated at the peaks and bottoms are the top and bottom cuts of each, and it will be noticed that no two bevels are alike, so that each rafter must be carefully laid out and marked for each particular corner. There will be four hips of different lengths and with different bevels, so they must be properly framed. In regard to the jack rafters they are shown on the right side spaced out on the wall plate from X to D, against the hip, G D. Their top down bevel or plumb cut will be the same as that at P, that at R will be the side bevel. Similarly with those from D to M, the plumb cut will be the same as P, but the bevel will be that at O.

In order to develop the planes of this roof, commence by drawing E U S, from E, at right angles to E F, or A B; also draw F V T, parallel to E U S. Make A S equal to A H, by taking A as center with radius A H, and striking the arc H S. Through S draw S T, parallel to A B. If a center be taken at B, and an arc struck as I T N, it will be found that the arc will pass through T, or F V produced at T. The surface A S T B will cover the plan A E F B on the pitch E H.

Draw E J square to A C, and produce to K. Sweep

H S to K, and join A K, and K C. A K C, will be the covering plane which will cover over A E C on plan. For the plane of C E G D, draw E W, square to E G, and produce to Q. With C as centre and C K as radius, strike the arc K Q.; draw Q R, parallel to C D. Join C Q which will be the centre of the hip rafter on this side. Draw G X, square to C D, and produce to R; join R D; C Q R D will be the covering plane which will cover over C E G D, on the pitch G P.

Now draw G M, and F L, square to B D, and produce them to N and O. With D, as centre and D R, as a radius describe the arc R O, also the arc T N. Join N O and N B; B N O D, will be the covering of the plan B F G D, on the pitch G P. Q R Z, will be the covering of deck, being the same size or area as E F G.

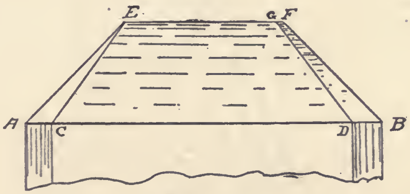

Fig. 10.

At Fig. 10 will be seen the elevation, or as the roof will appear when framed, raised and covered.

A model can be made of this roof by cutting out the entire outside line of the covering and making a slit from A to B, from B to D, from D to C, from C to A, also from Q to R, which being folded up will show the completed roof with the rafters, cuts and bevels in position.

CHAPTER V.

Square Pyramidal Roofs.

Roof framing is a study well worthy the attention of every student of building construction. The roof illustrated and described in this chapter is one which occurs on many cottages and houses now-a-days. It is one of a kind of tower roofs on a square plan or as they are sometimes termed "Pyramidal roofs." A C D F

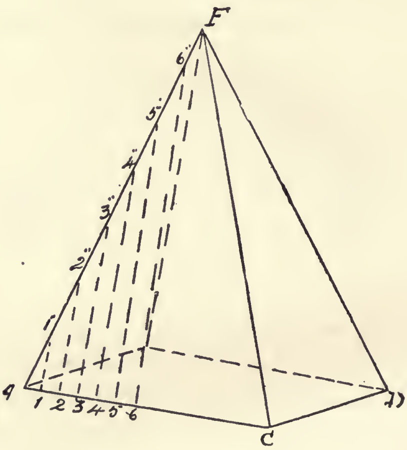

Fig. 11.

Fig. 11, is the projection of the roof completed. A C D B Fig. 12, the plan of the roof on the plates; AE, CE, DE and BE being the hips which form the shape.

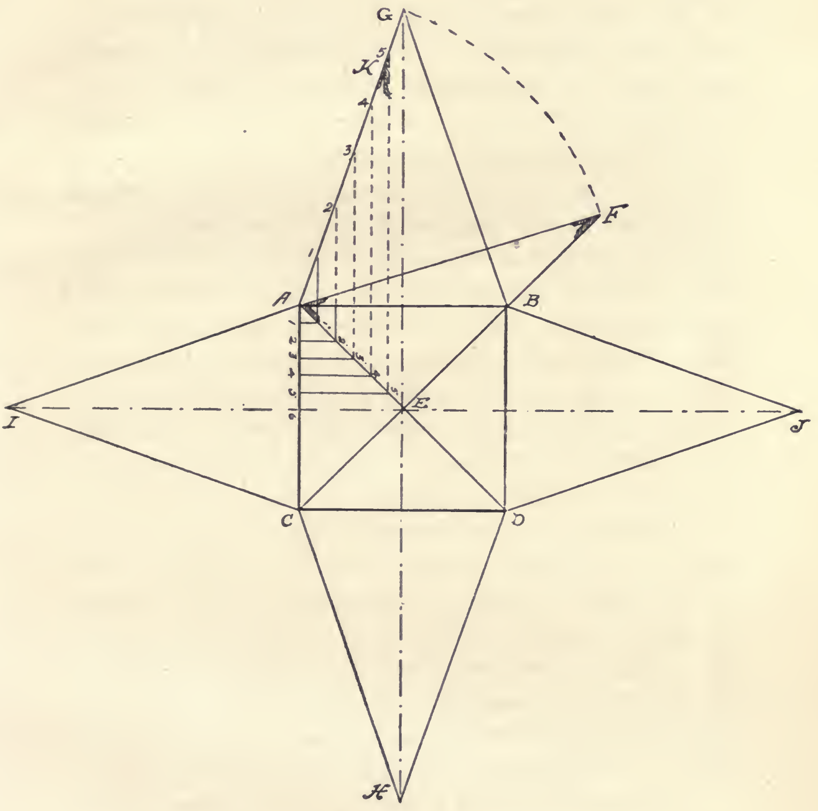

Fig. 12.

of the roof or seats over AF, CF, DF, Fig. 11. The fourth hip over BE, cannot be seen on the projection, Fig. 11.

In order to find the length of the hips, produce the line E B indefinitely. Now set off, measuring from E, the height of the peak to F, Fig. 11. Join AF, Fig. 12, which will be the exact length of either of the four hips. In framing this roof it is best to let two opposite hips as BE, and EC, on the same line abut against each other at the peak, and to cut off their thickness from the other two top or peak cuts, thus: If BE, and EC, be each 2 inches thick then 1 inch will be cut off the peak cuts of AE, and DE which rest against them at E. This is done in the same manner, as every top cut of a rafter resting against a ridge must have half the thickness of the ridge cut from each rafter. The bevel at F, Fig. 12, is the bevel of all four top cuts and that at A, the bevel for the cuts on the plate.

Concerning the jack rafters, the best way to determine their length is to set them off on the plate as from A to C, Fig. 12, then to draw a line as H E G through E, parallel to AC, or BD. With A, as centre and AF, as radius describe the arc FG, cutting the line H E G at G. Join G A and G B. The triangle, or more properly speaking, the triangular surface G A B will be the exact covering surface of the roof plane A E B.

From where the jack rafters come against the hip AE, draw lines parallel to E G, and square to A B, cutting A G, as shown. The lines reaching from the plan line A B to A G, will be the exact jack rafters and the bevel at K, will be the side cut against the hip, with the bevel at F, as the vertical cut, and that at K, the bottom or plate cut.

The development of the covering for the remaining three planes of the roof is found by drawing the line I J, through E, parallel to A B, or C D; then with B, as centre and B G, as radius describe an arc intersecting E J at J; join J B and J D. A similar process can be gone through to determine the points H and I thus obtaining the four converging planes.

To prove the accuracy of this and the two previous roof problems before described, or in fact any roof problem, the plan should invariably be laid out to a scale, say 1½ inches to 1 foot, on a sheet of cardboard (½ inch scale will do if the roof is very large), and a cardboard model then made. To do this, when the lines have been laid down, as just described, the entire model may be made as follows:—With a sharp pocketknife cut clean through the cardboard from A to G, from G to B, from B to J, from J to D, from D to H, from H to C, from C to I, and from I to A. Next make a slit halfway through the cardboard from A to B, from B to D, from D to C, and from C to A. Proceed to fold the planes over the seats till they all join at the edges, thereby making a completed cardboard roof resembling Fig. 11 with the jacks and bevels in position, and with all the cuts fitting as they ought to.

CHAPTER VI.

To Frame a Pentagonal Roof.

Some time since the writer was required to lay out a pentagonal or five-sided band stand which had a slate roof terminating in a wooden finial at the apex. As this roof is of a form rarely met with in building construction, I introduce it here, being under the impres-

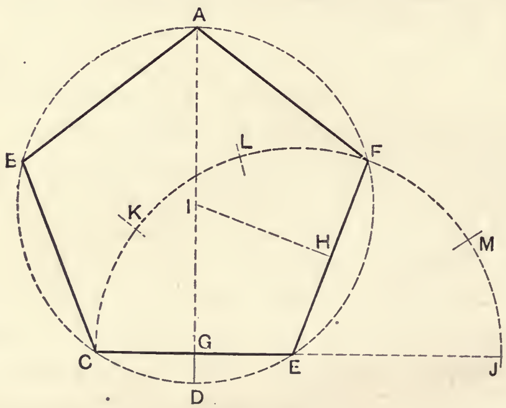

Fig. 13.

sion that readers might perhaps have occasion to use the lines for such a roof. However, as there are pavilions, pagodas or summer houses built on this plan, I think it wise to describe it as the knowledge is easily carried and may prove useful.

Fig. 13 illustrates the simplest and most accurate method of striking out a *pentagon*, or five-sided figure, one side being given. For example, if the length of one plate line as E D, Fig. 14, be drawn to a scale on any plan, the carpenter can very readily lay out his pentagon full size or half size, as follows:—Let C E, Fig. 13, be any line equal to the line E D, Fig. 14. Divide C E, into two parts at G, and produce C G E. Make E J, equal to C E, and with E, as centre and radius E C, describe the semi-circle C K L F J. Divide the semi-circle into five equal parts at the points K L F and M. From the point G, square up the line G I. Join E and F, and bisect the joining line E F, at H. From H, square out, cutting the line G I, at I, and with I as centre and I F as radius, describe the circle A B C D E F. Set the compasses or a rod to the length C E, or E F, and space off round the circle, also join the points together by lines and complete the *pentagon*, as indicated by the heavy black lines.

In order to lay out the hip and jack rafters for a roof of this description, proceed to Fig. 14, and lay out the outside lines of the plates as A B, B C, C D, and D E, also with the compasses, describe the thickness of the finial or boss, against which the top ends of the five hip rafters rest, also lay out the hip rafters as indicated in the diagram in three lines; the centre one being the line of the *backing*, and those on either side the thickness of the hip. By *backing* is meant *beveling* the top edges of the hip to permit the roof-boards or sheathing to lie on the solid timber instead of only on the sharp *arris* or edge of the rafter. The seats of the jack rafters may also be laid down as shown. To find length of hip rafters join the centre or apex and B, Fig. 14. Square up from the apex as X, equal in height to the pitch or rise of the roof. Join B and Y to obtain the length of the hip and its apex and plate cuts, seen in the diagram.

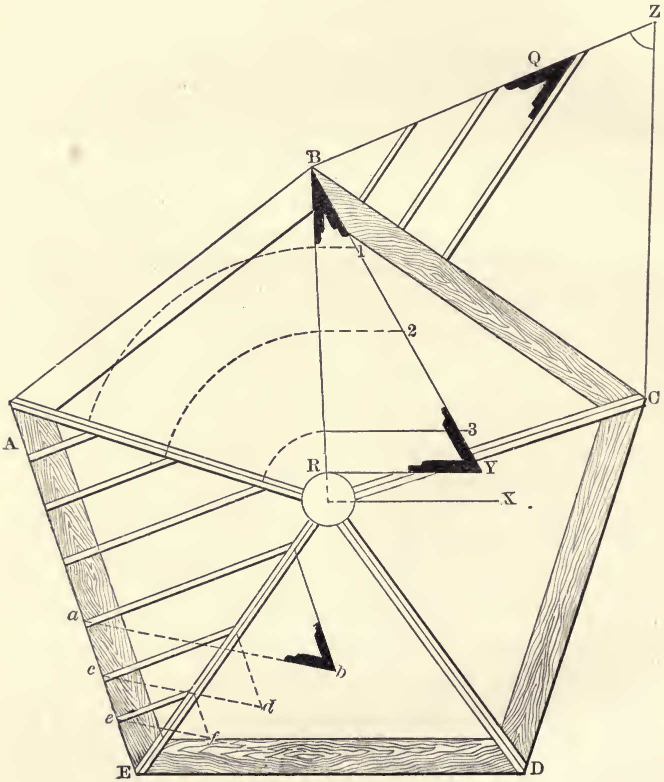

Fig. 14.

There will, of course, be five hip rafters of this length required. The length of each jack rafter may be obtained in a very simple way by squaring up from each jack where each rests against the hip and setting off each height of the jacks, thus determining the exact length of B Z C, being the devolopment of the B R C. The side bevel will be as Q, which must be reversed for jack on opposite sides of the hips: There will be five sets with a right-hand side bevel and five sets with a left-hand side bevel.

Regarding the backing of the five hip rafters, the first thing to be done is to find the desired bevel. This is easily accomplished by taking any point, as s, Fig. 15, and from s, drawing square to E R, as O P. From

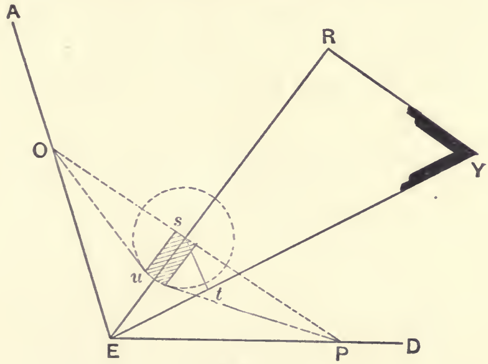

Fig. 15.

s, let fall a line perpendicular to E Y, as s t. With s as centre and s t as radius, describe the circle s t u cutting R E, at u. Join u P and u O. O u P, will be the bevel of the backing and a bevel may be set to one side of the rafter.

CHAPTER VII.

Hexagonal Pyramidal Roofs.

Readers will see at Fig. 16 the top and side views of a hexagonal or six-sided roof, or one which has a wall plate running round on six walls as shown above, the dotted lines representing the angle lines of the hexagonal figure. The completed roof with the boarding or tin on will appear as shown on the lower sketch.

In order to frame this roof the following system should be used:

At Fig. 17 proceed to lay out on a board or paper to a scale of 1½ or 3 inches to the foot, the plan of the wall plates (on the outside line) A B C D E F. Join the points of the intersections of the sides, as A D, B E, and C F; passing through the centre G. This gives the seats of the hip rafters A G, B G, C G, D G, E G, and F G; six in all. To find their exact length, square up from E G, as G J. Lay off also to the same scale, the exact height in feet of pitch or rise of the roof from G to J, and join J E, which line will be the exact length of the hip rafter as seen in the diagram with the top and bottom bevels necessary for the cuts, these being given at once without any uncertainty.

To find the length of the common rafter, to stand over H G, set off the pitch G I, on G C, equal to G J, and join H I, for its length. This rafter is rarely used on roofs of this class, except when they are of large area, as only the jacks are requisite, especially on modern frame houses where they seldom exceed eight feet in width, thus requiring short rafters.

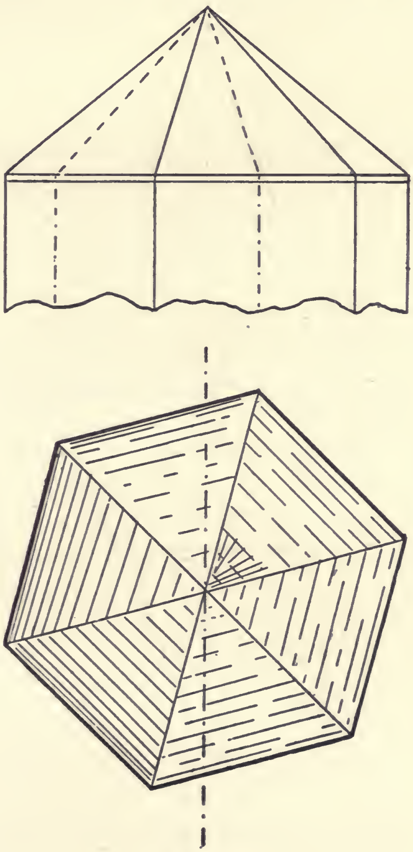

Fig. 16.

To develop this roof take a pair of compasses, and with E, as centre, and radius E J, describe the arc J M L, cutting H G produced in L. Join E L and D L which will give the triangle E L D which is the covering over the plan E G D, on the pitch or rise G J. Bisect, or rather divide E F, into two parts at Q. Square up from

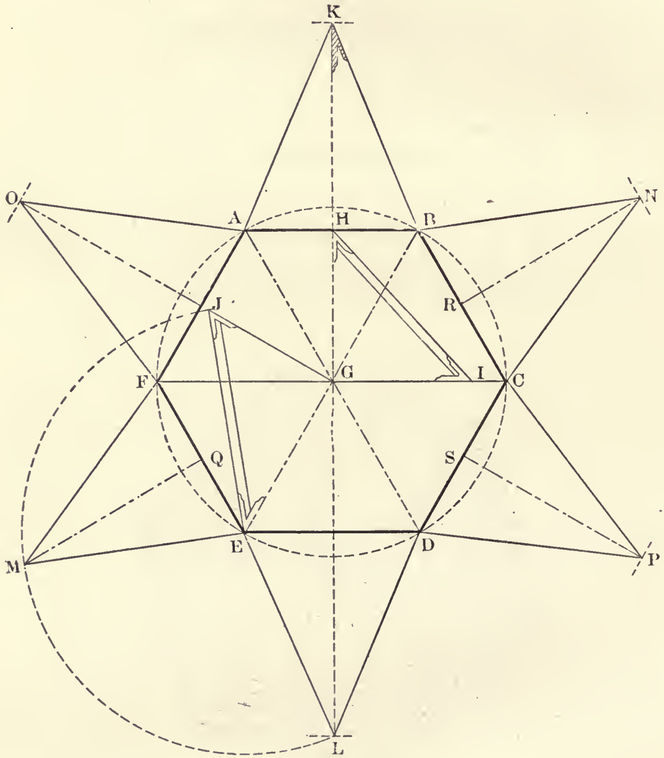

Fig. 17.

Q, cutting the arc J M L, at M. Join M E and M F. The triangle E M F, will lie over E G F. The remaining four triangular developments or coverings can be laid out from the foregoing by making J O, H K, R N, and S P, equal in length to Q M, or a simpler method would be to take G, as centre with G M, as a radius and describe short arcs cutting O, K, N, and P, thus giving the exact lengths at one sweep, and insuring their being alike so as to meet at the centre G when folded.

The side bevel at K, will make the top cuts on the jack rafters fitting against the hips, the bottom cuts fitting on the plates being the bevel at H.

Almost every mechanic knows how a hexagon or six-sided figure is struck out, still in case there should be even one student who is at sea in regard to it, I repeat the method of doing so here. The diameter or length from angle to angle is usually given, or if not, is easily found by joining the angles as before described. Now to lay out any hexagon, draw any line as F C, and divide it into two equal parts at G. With G as a centre and radius equal to G F, strike the circle A B C D E F. Now take a pair of dividers (sharp points on both legs) and from C, with one point on C, space out the six distances C B, B A, A F, F E, E D, and D C. Draw the lines as shown for the outline of the hexagon.

CHAPTER VIII.

Conical Roofs.

Having treated the usual forms of roofs embracing the hip and valley principles, I will now draw attention to the proper laying out and framing of a roof on a circular tower, as this form occurs very often in modern houses, barns, etc. The methods to be followed in this chapter are very simple, so that an ordinary mechanic can easily understand them if he only studies the diagram and text a little.

Supposing A, B, C, D, E, F, G, H, on Fig. 18 to be the plan or plate line of the roof, and O L, the pitch or rise, it can be laid out as follows: To be more explicit I will take it for granted that a carpenter has a roof to frame with a plan A, B, etc., of 6 feet diameter, or 6 feet from C to G, and 9 feet rise, or 9 feet from O to L. Proceed to strike the plan A, B, etc., either full size or to scale. It is always better to lay out full size if a floor or drawing-board can be found big enough to do it, but if not half size or a scale of 3 inches or 1½ inches to the foot may be used.

Having struck the circle draw centre lines for the rafters A E, B F, C G, and D H, and set off the thickness of the rafters as they show on the plan. Next draw any straight line as J K, the same length as C G; raise up the centre line O L, the height of the pitch, and join L K, which will be the length of the rafters to stand

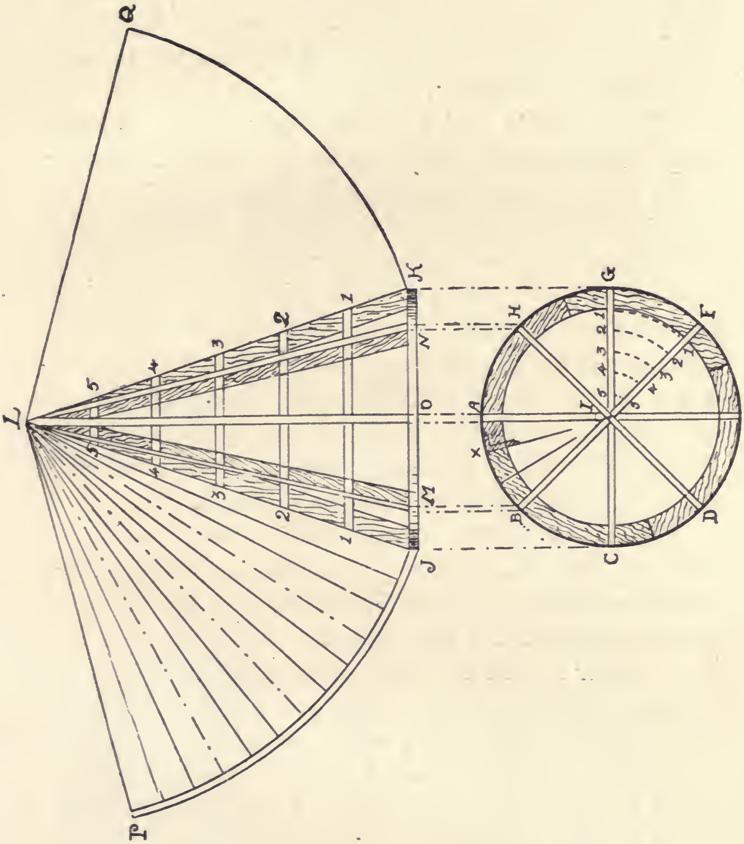

Fig. 18.

over A I, B I, C I, D I, E I, F I, and G I and the top and bottom cuts will be directly given; as at L and J, L M and L N are the rafters I D and I F placed in position and L O is the rafter E I in position. By referring to Fig. 19 the rafters B I, A I and H I will be seen at the rear of the figure.

If the roof is to be boarded vertically, horizontal strips or *sweeps* will require to be sawn out and nailed in the manner represented in both Figs. 18 and 19. To do this properly, divide the height from O to L in Fig. 18 and draw the lines representing the sweeps as 1 1, 2 2, 3 3, 4 4, and 5 5. The neat length, and the cuts to fit against the sides of the rafters may be determined by striking out the sweeps shown on the plan, 1 1, 2 2, 3 3, 4 4, and 5 5. It will be noticed that this roof will require 8 circular pieces for each row, or 40 sweeps in all. One pattern will do for each sweep and the remaining 8 needed can be marked from each pattern.

Fig. 19 will convey a better idea of the constructed roof, as this illustration represents each stud, plate, rafter and sweep in its fixed position, with the covering boards nailed on half way round.

In order to find the exact shape and bevels for the covering boards, a very simple method is used, thus: Take a pair of compasses, or a trammel rod, and with L as centre, (Fig. 18), and L P as radius, describe the arcs J P, equal to the semi-circle A B C D E. and K Q, equal to the semi-circle A H G F E. Join L P and L Q, now divide J P into 12 equal spaces with a pair of compasses, and join the division marks on J P with L. This will give 12 tapering boards and the bevel at X on the plan will be the bevel of the jointed edges. As

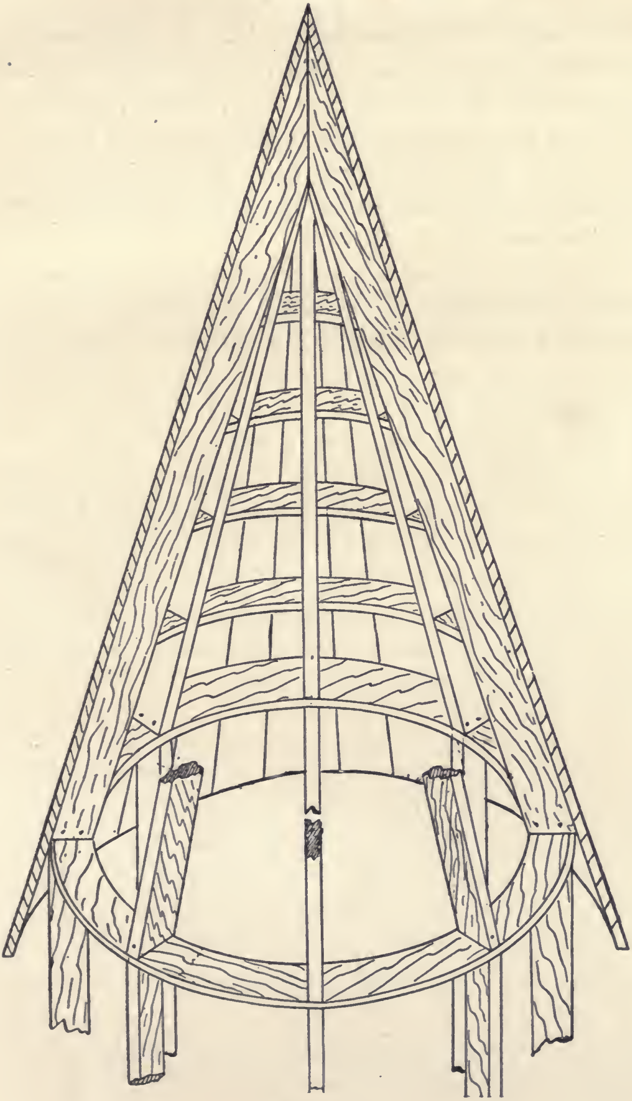

Fig. 19.

twelve boards will be needed for half the plan, twenty-four will have to be cut out for the other half, so it will be seen that if the sweep or arc J P goes round from A B, etc. to E, the sweep K Q will go round H, K, G, etc., to E. The diminishing lines from the point L to the line J P are the inside lines of the joints of the boards shown also in Fig. 19.

In order to prove the accuracy of the foregoing, a model can be made by drawing the roof to scale on cardboard, and then cutting out the figures from L to J, from J to K, and from K to L. Also cut out the figures L P J, and L Q K. Now if L J K be stood up over A E, B F, etc., it will be seen to fit over each.

In a similar way the figure L J P will bend around A B C D E with the peak L over the point I and the line J P around A B C D E. In a like manner K Q will bend around A H G F E, and L will lie over I, thus proving the correctness of the methods followed. Care must be taken to allow for the intervening rafters when framing the peak cuts of the rafters.

CHAPTER IX.

To Frame a Conical Roof Intersected by a Pitched Roof.

As this is a roof which occurs in many cases, especially in railroad work, it will be found both interesting and useful.

Let A E F B, Fig. 20, be the plan or wall plate of the conical dome, and A D B, the diameter, D C the rise or pitch. Join A C, to obtain the lengths of the common rafters which will radiate from the centre C, round the circular plate A E F B, with the top and bottom bevels as represented at C and A.

On account of the pitched roof C H F, the gable end of which is G I H, with pitch J I, equal in height to D C, intersecting or cutting into the conical dome, there will be a valley rafter. The seat of this valley will be D F, because J I, being equal to C D, the ridge J E, will be the same height as the conical apex or peak D.

To obtain the length of the valley rafter, square up from D on D F, and with D, as centre and D C, as radius, cut off the length D K, equal to D C. Join F K, this will be the length of the valley, and as D B, is equal to D F, and the pitches D C, and D K, are equal, therefore the valley will be the same length as common rafter.

To find the lengths of jack rafters, proceed to Fig. 21, and lay out the ridge and valley rafter as before.

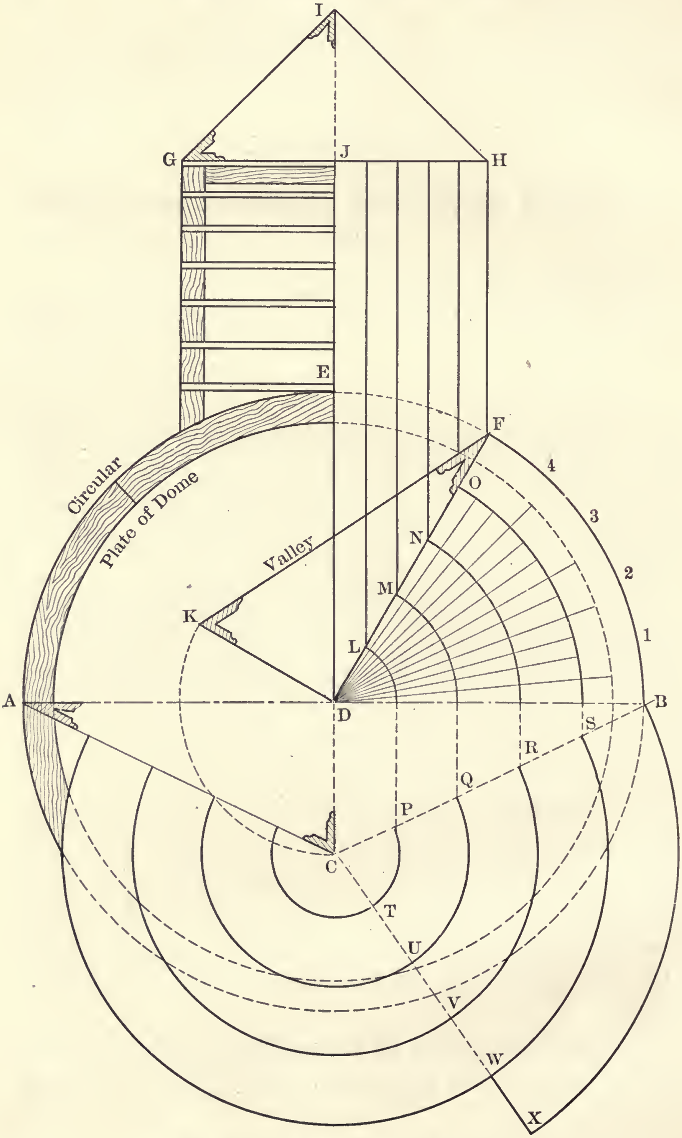

Fig. 20.—Laying out of Roof.

With F as centre, and F K, as radius, describe the arc K Z, cutting the ridge at Z. Join F Z. The lengths of the jacks will be as shown on the left side of the ridge.

The final process is to determine the shape of the covering or roof boards which are laid horizontally. To

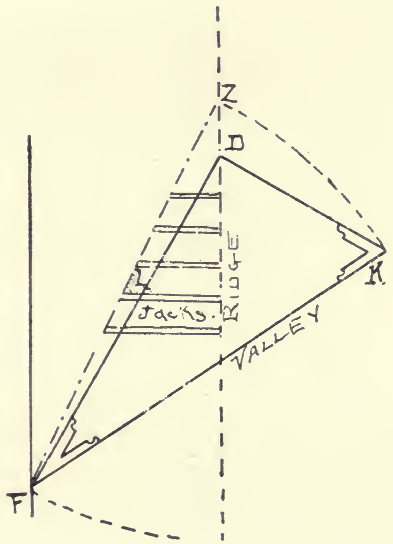

Fig. 21.

do this take C, Fig. 20, as center, and with equal spaces up the common rafter as P Q R S, strike the parallel curves P T, Q U, R V, and S W. The exact length of the boards is found by dividing F B into five equal parts and setting them off on B X. Join C X, to determine the length of all to the apex. A very successful card-board model can be made of this roof.

CHAPTER X.

Octagonal Roofs.

At Fig. 22, A B C D E F G H is the plan of the octagonal roof. I is the centre or peak. A I, B I, etc.,

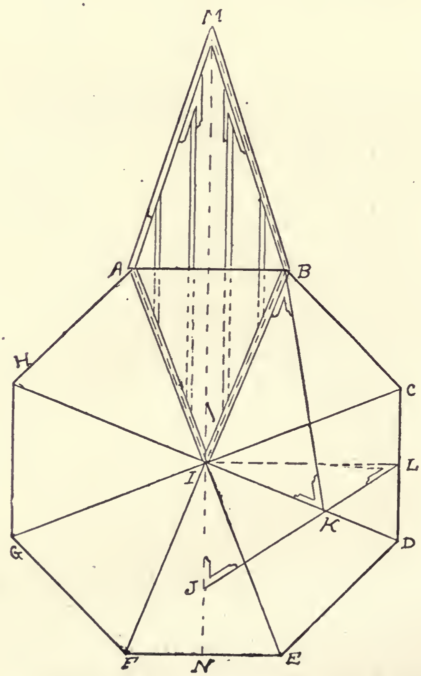

Fig. 22.

are the seats of the hips. L J is the length of the common rafters. B K is the exact length of the hip rafters.

To find side bevel of hips, produce N I to M, and make B M equal to B K ; join M B and M A. The bevel at M will be the side bevel across the top edges of the rafters, and the bevel shown inside the hips will be the bevel across the top edges of the jacks, right and left hand.

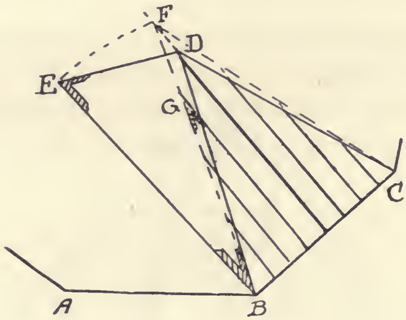

Fig. 23.

Proceed to Fig. 23, and to obtain side bevel of octagon hip rafters, on B D, the seat of the hip, raise up the pitch D E, join E B for length of hip. To obtain side bevel of backs, take B as centre and B E as radius, describe arc E F and join F and B. Produce line of jacks to meet B F, and the bevel at G is the side bevel across top of jacks, applied right and left, and on right and left, and on right and left sides of hips.

CHAPTER XI.

Framing an Octagonal Roof of Gothic Style.

As all are interested in unusual problems in carpentry, I have pleasure in laying before them in this chapter one which I solved and which is worth studying out. It was erected on a cupola of a large institution

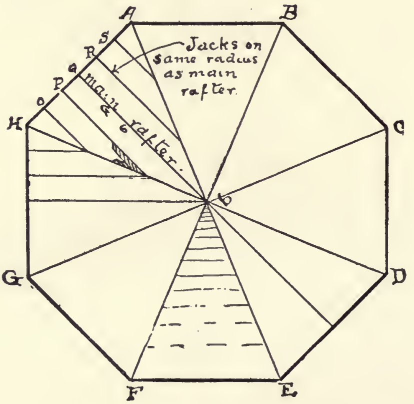

Fig. 24.

building in the city of New York, and is to-day standing complete according to the architect's design.

A B C D E F G H, Fig. 24, was the plan of the cupola or lantern, eight-sided in shape as will be seen. Its elevation was as represented in Fig. 25, and its section was a gothic of the equilateral form, as G 6, D 6, Fig. 25. F 6, and E 6, were the hip lines of the octagonal plan to stand over the seats F 6, and E 6, on Fig. 24. The radius of the gothic was as shown on the elevation, and from this we will proceed to lay out the roof and get the curves for the timbers as shown in Fig. 26.

From the points T, U, V, W, X, draw lines square to Q 6, as TL, UM, VN, WI, X. From the space points on the line QZ, make the dotted lines equal in length individually to TL, UM, VN, WI, X; and draw

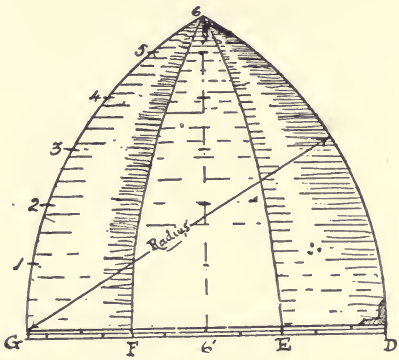

Fig. 25.

through the points the curve Z Y G. Produce US, and WR to Y and Y', and the lines SY' and RY will denote the curved jack rafters. The bevel at Y, is that which will fit against the side of the hip rafter as the development G, Z, Q, will fold and stand over the G 6, Q. The curve of the jacks will be same as G 6, Fig. 24, and struck from the same radius. This will be readily understood by an examination of the diagram, Fig. 26. The bevel at 6, Fig. 25, will be the plumb cut of the jack rafters.

In order to find the length and curve of the hip rafters which will stand over the seats, A 6, B 6, C 6, D 6, E 6, F 6, G 6, H 6, Fig. 24, proceed as follows: Take any octagonal triangle as G 6 F, Fig. 24, and lay it off as G 6 F, Fig. 26, G 6, being a level line. From

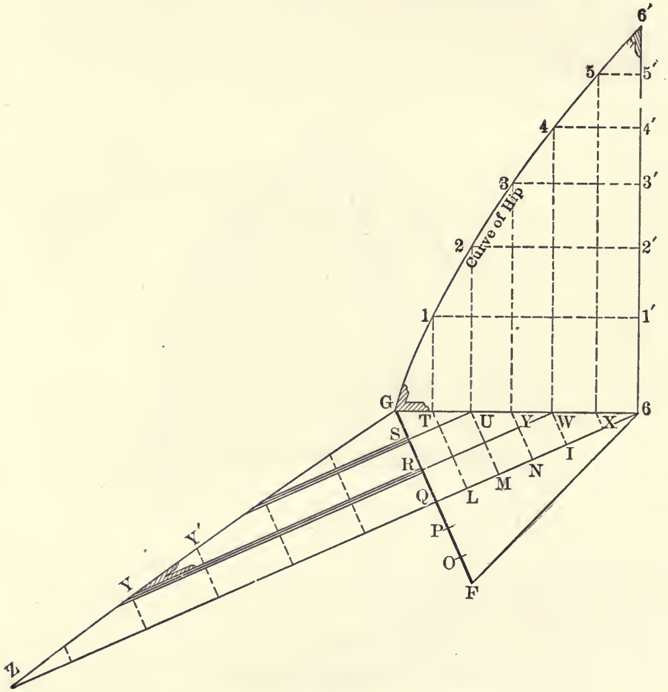

Fig. 26.

6 raise up a plumb line as 6, 6'. Next divide the gothic sweep on Fig. 25, G 6, into six equal parts, as 1, 2, 3, 4, 5, 6, and carry these over to the centre line as indicated. Transfer these to 6 6', Fig. 26. Next divide the line G 6, into six equal parts, as T, U, V, W, X, and

from the points of division raise up plumb lines. Also, draw level lines from the points 1', 2', 3', 4', 5', on 6 6', cutting the plumb lines from G 6, at the points 1, 2, 3, 4, 5, 6. Draw the curve G 1, etc., through these points and this curve will be the exact shape of the hip rafter required to stand over the eight seats seen on Fig. 24.

For the jacks divide the plate G F, Fig. 26, into six equal parts and draw lines square to the plate for the seats of the jacks, as will be seen from A to H, Fig. 24. These will join with the lines 2 U, 4 W, at the points U and W on the line G 6. Produce them indefinitely outside G F. Now take the divisions H A, Fig. 24, and set them off on the line Q Z, Fig. 26, and draw lines square to Q Z.

CHAPTER XII.

Framing an Octagonal Molded Roof.

The molded roof which I propose to treat in this chapter is one which may not be familiar to readers and may seem difficult to lay out. Various methods have been put forward for the purpose of getting the exact cuts, etc., for these roofs, but there have been none so far sufficiently intelligible to apply practically. I have, therefore, worked out one of the most usual forms for the benefit of the trade at large.

The first roof is a regular "ogee" molded tower roof on an octagonal or eight-sided plan, or, in other words, the plate is eight-sided, as represented at Fig. 29, where the plan of the rafters is denoted, including both hips and jacks. C D E F G H I J is the eight-sided plate, and eight sides have a molded plane terminating in a point at L, shown in the layout, Fig. 30.

As there may perhaps be some readers who are not entirely familiar with the proper ways of making an eight-sided figure or octagon, I will explain this here. Let *a b*, Fig. 27, be one side of the octagon, say 4 feet long, it is required to construct the full octagon 8 feet 6 inches wide. To do this: With the steel square or bevel, draw *a d* and *b c* on a miter, and make each 4 feet long; then from *c* and *d*, draw *c e* and *d h*, square to *a b*. Next from *e* and *h*, draw *e f* and *h g*, on a miter of 45 degrees, and make each 4 feet long; join *g* and *f* to complete the figure. This alone is one way to do it, and a very simple one. Fig. 28 shows another way: Let *a d*, *d c* and *c b* be any square, say 8 feet 6 inches wide. Draw the diagonals from corner to corner, as *a c* and *b d*, cutting in *e*. Now with the compasses set to *e c* mark the sides at *j* and *k*, also at *h f*, etc. Join these points and the eight-sided figure will be given, as shown by the heavy black lines in the engraving.

By either of the above methods the plate line, C D E F G H I and J of the plan, Fig. 29, may be exactly

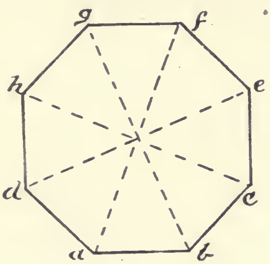

Fig. 27.

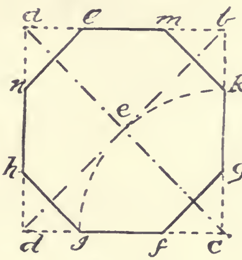

Fig. 28.

laid out, or if the cuts or octagon mitres are to be found, the figures 7 and 17 on the steel square will give the cut. The writer prefers, however, to lay out roofs of this character *full size*, on an extemporized floor or drawing-board and to strike out the rafters also full size with a trammel rod, a bradawl and a pencil. K A B L Fig. 30, is the profile of the roof, K A and K B being jack rafters, which will stand over those marked on Fig. 29; A corresponding to A, and B to B. The bevel at X, is the side bevel of the jacks fitting against the hips, right and left. The layout will explain this very clearly.

To find the exact shape of the hip curve, as P 10' Fig. 30, draw O 10', the seat of one octagon angle or

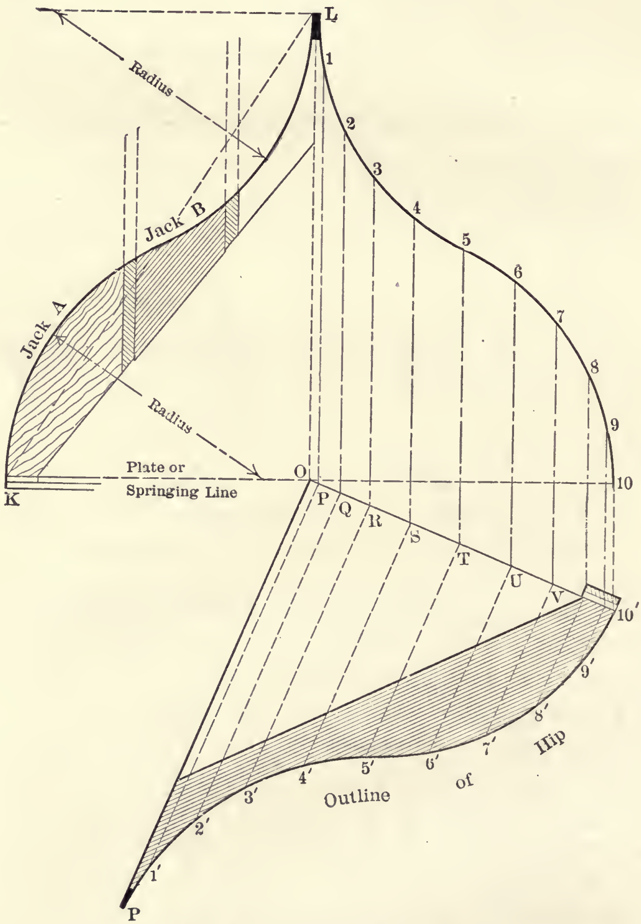

Fig. 30.—Layout of Roof.

hip rafter, and from O draw O P square from O to 10'. Divide the "ogee" line L 10 into 10 equal parts with the compasses in the manner shown, commencing at L. Draw lines from the dividing points, plumb to the plate

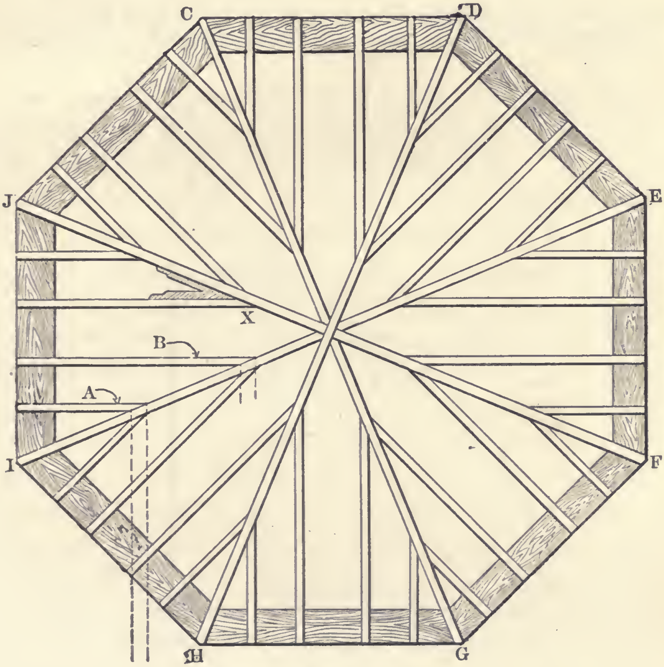

Fig. 29.—PLAN OF ROOF.

or spring line K O 10, and produce these lines till they cut the hip seat O 10', as P, Q, R, S, T, U, V, W, then from the points where they cut draw lines down, P 1', Q 2', etc. Finally, make the heights of these lines equal to the heights on the regular "ogee" roof above, and trace through the points P, 1', 2', etc., the curve marked

"Outline of Hip" for a pattern rafter for all the eight hip rafters required.

Readers will find in the sketch, Fig. 31, a very simple method of finding the side cuts of the jack rafters. To square across from the side of the rafter where the thickness of the jacks rest against it as shown here, and

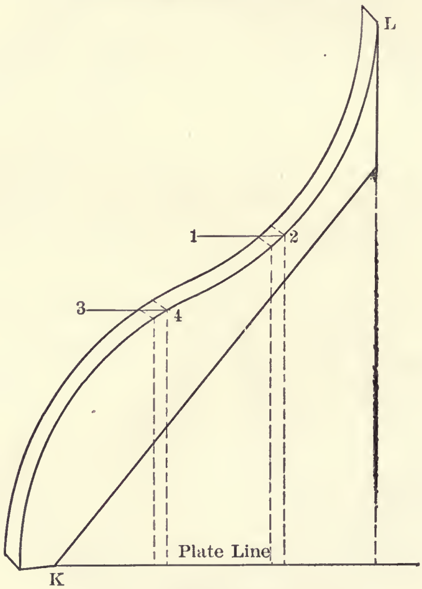

Fig. 31.

to join the opposite corners for the bevel as 1-2 and 3-4. Another way to find this cut is to develop the roof in the way I have described in previous chapters. And still another is to apply the steel square on the bottom side, using the ordinary octagon jack rafter cut. The plumb cut being always the same. As the jacks and common rafters have the same profile they must coincide.

CHAPTER XIII.

Framing an Octagonal Roof with a Circular Dome.

At Fig. 32, let A B C D E F G H, be the plan of the wall plates of the main octagonal roof and H O, G O, G N, F N, F M, E M, E L, D L, D K, C K, C Z, B Z, B J, A J, A I and H I, the seats of the octagonal hip rafters. The intervening planes between the hips will be circular surfaces as O N, and the rafters, if cut in horizontally as shown in the engraving, will be curved on the outer edge and each sawn to a different radius using the centre of the octagonal plan and upper circular plate J Z K L M N U O I, as a fixed centre and increasing the radius for each sweep as they go down on the pitch in the manner seen in Fig. 33, where the sweeps are represented cut in between two hip rafters, the bottom cuts of which rest at the angle of hip; this will also be seen on the plan Fig. 32, as G O and G N. The upper ends or cuts of the octagonal hips are cut to, and notched under, the upper circular plate which carries the studding, forming the drum of the dome.

Concerning the length of the hips, jacks, and common rafters, readers will find the simplest method of determining their length to be that shown on the diagram Fig. 32. To obtain the length of the main hips as G N, and so on, lay off the seat F M, and square up from M, as M R. Join R F, which will be the exact length of the hip, to scale, and R, and F, will be the top and bot-

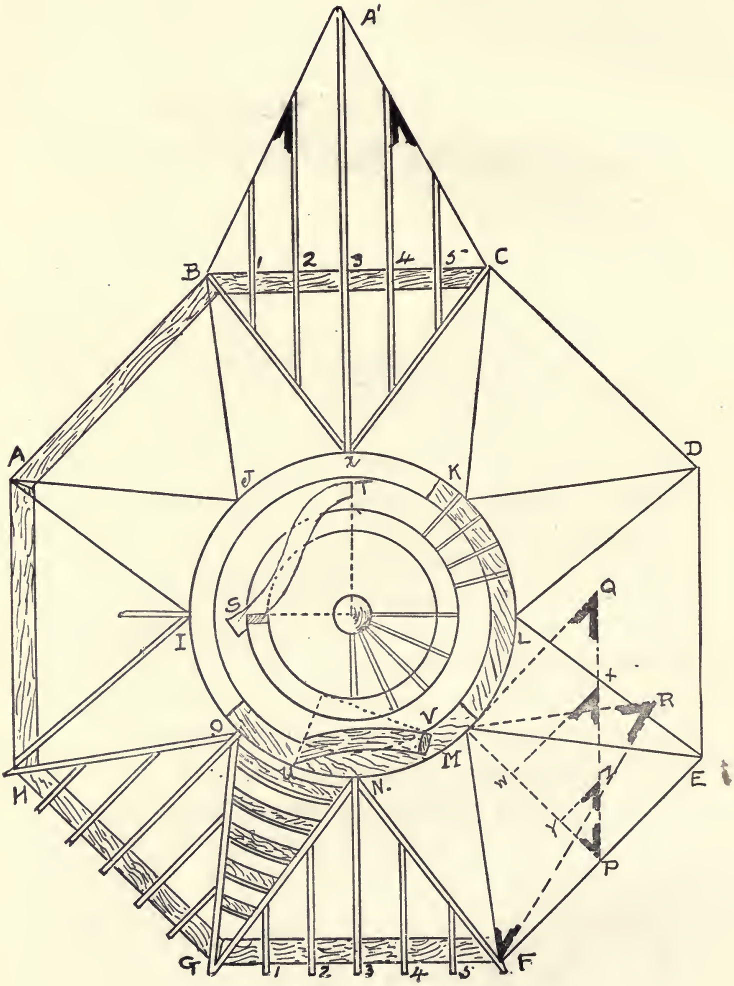

Fig. 32.

tom bevels. For the common rafter as 3 N, divide F E into two equal parts at P, square up from P as P M, and from M square up as M Q, and join P Q, which will be the length of the common rafter to stand over the seat 3 N. For the jacks from P, on the line P M, set off the distances from the line of the outside of the plate as 1, 2, or 4 and 5 to the point where each comes against the

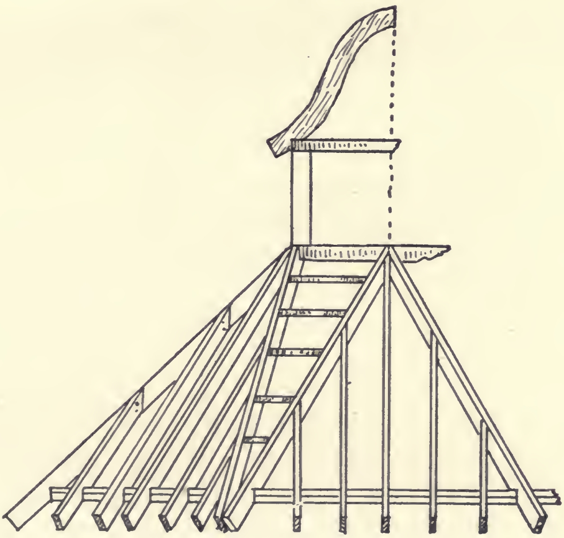

Fig. 33.

side of the seat of the hips G N, and F N, as P Y, P W. From the points W and Y square out till each line cuts the line P Q at X and Z; P X and P Z, will be the exact length of each jack to the longest point.

The curved stud for the drum U V in Fig. 32, shows how the design of the roof may be made more graceful by introducing curved studs instead of the straight studs seen in Fig. 33. S T shows the ogee rafters of the top or *dome*, and with its rise or rim. A B C on the top of the engraving illustrates how this roof may be developed in the way I have illustrated and explained in the previous chapters, as I have by slow degrees led up from the simplest to intricate roofs and their framing.

CHAPTER XIV.

To Frame a High Pitched or Church Roof.

At Fig. 34 let A B C D E F G H I J K L be the plan of the wall plates. Around to B will be a circular end. B Y the pitch or length of common rafter which will space along the plate from B to C and from A to L. The bevel at Y will be the one required for the top cut against the ridge and that at B the bevel for and on the wall plate. Similar rafters will require to be cut for the semi-circular end and they will be spaced out equally round it as I have drawn them half way round from B to 8. On account of fitting the top or peak ends of these rafters where they group at the top it is advisable to insert a circular boss or block to fit them against; and the half thickness of this block must be cut from the ends of the rafters on the plumb cut. This is shown at X in the engraving. The ridge X Y will also require to be fitted to it and the common side rafters A X and B X. S T is the common rafter square to the plate and T U its exact length which will be found to be the same length as B Y.

C P, F P, L P and I P are the seats of the valley rafters with the jacks which will fit against all four. I have drawn these on one side only as the other three are duplicate rafters with the cuts reversed. The top cut is the same as Y, and the bottom side cut as W, which may be found by developing the roof. Z is the top cut

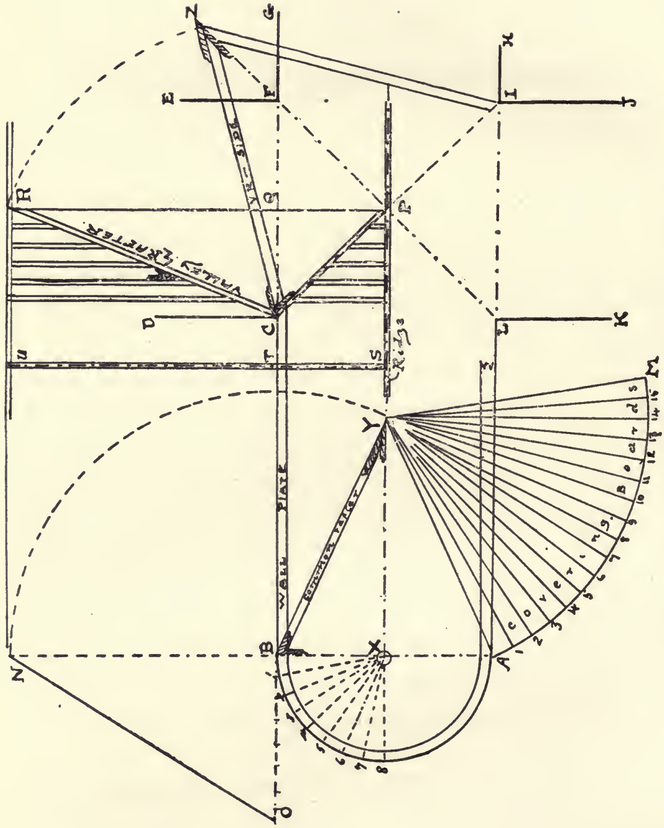

Fig 34 —Layout of a High Pitched Roof.

of the valley found by raising up the pitch P Z equal to X Y and joining Z I and Z C, and the bevel at C is the bottom cut of valleys.

In order to develop the planes of the roof produce the line C T B to any length. Produce A X B to N and with a pair of compasses strike the arc N Y cutting B N at N, through N draw N U R parallel to C T B and produce S T to U, also draw P through Q to R, and set off the valley and jacks in the manner shown. Next set a pair of dividers to one of the spaces round B 8 and set off the eight equal spaces from B to O. Join N O. If the whole diagram be laid out on a sheet of Bristol or cardboard a model may be made and the system proven by cutting the cardboard with a penknife or chisel from A to B, thence to O, thence to N, N to R, R to P, P to C and so on as before described. The shape of the covering boards may be determined by taking Y, as centre and with a length Y A striking the sweep Y M, then setting off on Y M 16 spaces each equal in length to 1, 2, etc.

CHAPTER XV.

To Frame a Mansard Roof.

Before commencing to describe the proper methods to follow in framing and raising a *Mansard* roof, I will first explain what a Mansard roof is. This form of roof derived its name from being constantly used by one

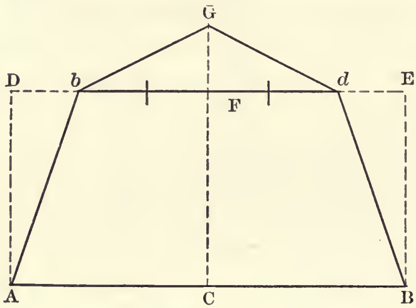

Fig. 35.

Francis Mansard, an architect who died in France in the year 1666. He was not, as is generally supposed, its inventor, as the idea had been previously adopted by such men as Segallo and Michael Angelo, in Italy.

The principal reason for the use of the Mansard form is to lessen the excessive height of a roof without resorting to a truss, and to obtain room space in the roof itself.

To describe or lay out a true Mansard roof, at Fig. 35, let C F, be the true height of the roof equal to half the width on the plate line C B. Draw D E, parallel to A B, and make D F, and F E, equal to A C, and C B. Join A D, and E B. Divide D F, and F E, into three equal parts and join A B and B D. Make F G, equal to d E, and join b G, and G d, thus obtaining the true form of the Mansard roof.

At Fig. 36 another way to describe this roof is shown, and this resembles more the old colonial, or what

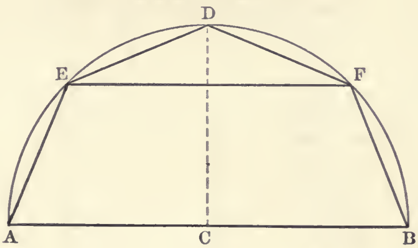

Fig. 36.

is called the American curb roof. To describe it strike the semi-circle A E D F B, from the centre C, with C D as a radius. Divide the semi-circle into 4 equal parts at E, D and F. Join A E, E D, D F, and F B, which will give the proportional form of the roof.

Fig. 38 will give the reader a full conception of the framing timbers of a Mansard roof as they will appear when raised. They consist of the usual wall plate and an upper plate which is supported by the *flaring* or sloping side rafters which form the Mansard chamber or attic within. Reference to the cross-section, Fig. 37, will make it clearer to the mechanic, as A, is the wall plate. E, the upper or Mansard plate supported by the Mansard or flaring rafters C, which flares 2 feet off the perpendicular. D, is the *deck* or upper rafters, and B, a tie or ceiling beam which gives a good attic room. Half the roof only, namely, the left side, is shown in the cross-section, Fig. 37.

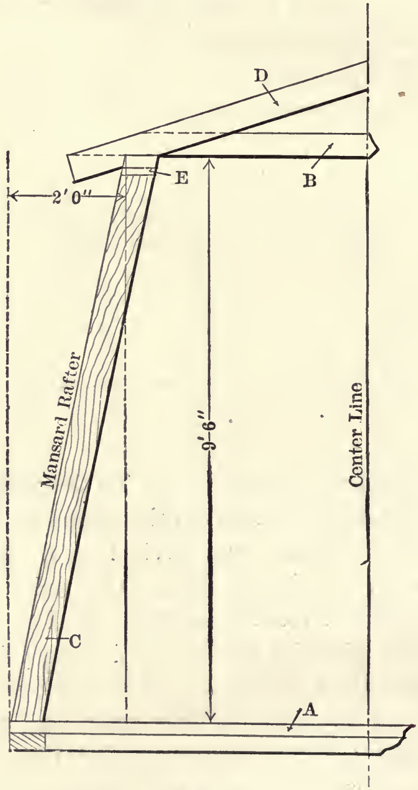

Fig. 37.

A comparison between the plan Fig. 39, and the elevation and cross-section will make clear the full construction of the roof and enable any mechanic to lay

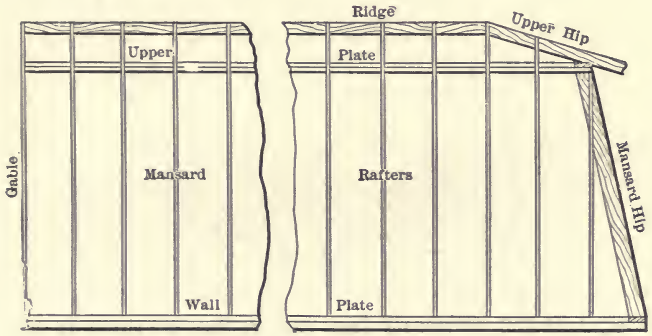

Fig. 38.—ELEVATION OF FRAMING.

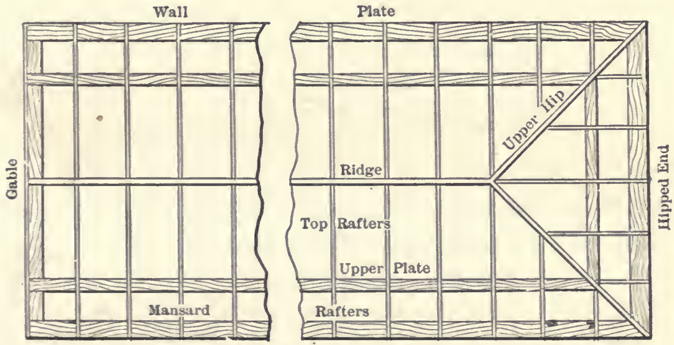

Fig. 39.—PLAN OF MANSARD RAFTERS.

out, frame and raise roofs of this class. The eleva ion and plan show one end (the right) hipped and the other (the left) gabled. In order to determine the exact

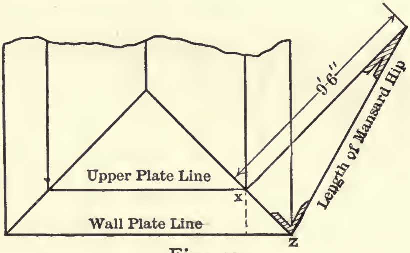

Fig. 40.

length of the Mansard hip rafter, the method is illustrated in Fig. 40. It is simply to raise up on the seat X Z, of the hip the height of the pitch 9 feet and 6 inches, and to join this height with Z.

The deck or upper rafters are framed in the way I previously described. Fig. 41 represents the proper

Fig. 41.

shape to frame the top cuts of Mansard rafters to prevent their slipping under the upper plate.

CHAPTER XVI.

Hemispherical Domes.

The roof presented to readers of this chapter is one well worthy of careful study and working out. It is of a kind which occurs on many houses now-a-days on the tops of towers for domes, etc. I should therefore recommend that all who have leisure time should work it out on a board to a large scale.

A B C D E F G, Fig. 42, is the plan, a perfect circle, of twelve feet diameter or six feet radius, A D and B F two diameters or centre lines intersecting in the centre. The dome is hemispherical or half a ball, or sphere, therefore the elevation H J I, is struck from a six foot radius. A pair of trammel points and rod may be used in striking out these curves, but, should these be lacking, a ¼ by ⅞ inch strip and a couple of brad awls will do the job very handily.

H I are the plates made of two thicknesses of stuff, and I J one pattern rafter. J is the top cut and I the bottom cut. They are, of course, similar. The rafters for this roof may be gotten out of 1½ or 2 inch stuff, fastened at the joint by a cleat as shown at I J. There will be eight rafters required (if it is intended to cover it vertically) as B X, C X, D X, E X, F X, G X, A X, and 3 X. Those will have horizontal sweeps nailed in between them denoted here by 1, 2, 3, 4, 5, in the elevation. The exact position of these sweeps is deter-

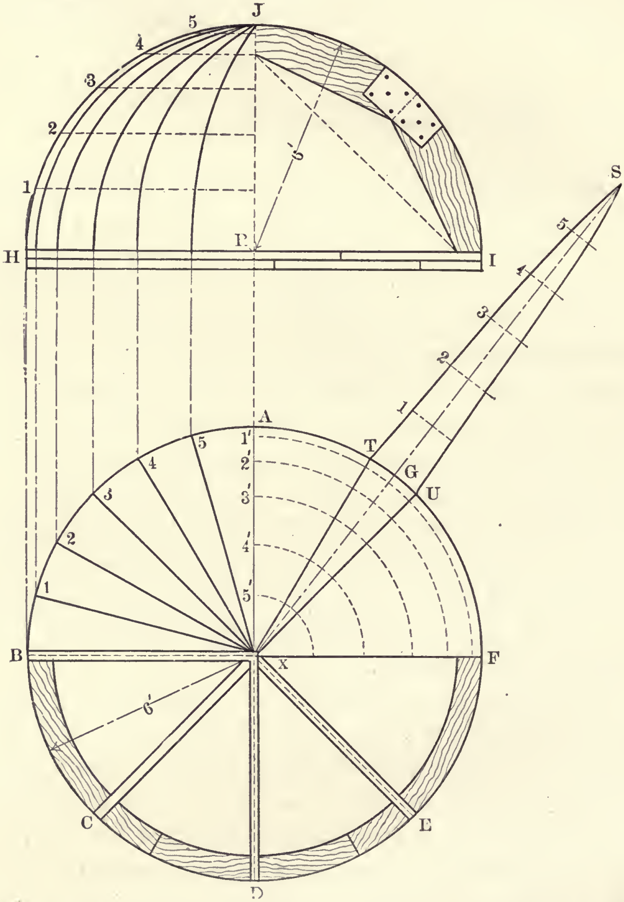

Fig. 42.—Methods for Obtaining Shape of Covering Boards.

mined by dividing the quarter circle H J into six equal parts and then from the division points, drawing lines parallel to H I. These will be the centre lines of the edges of the sweeps.

Similarly they are shown on the plan below as 1′, 2′, 3′, 4′, 5′, to X, which is as they will look from above. Their exact length for each course from 1 to 5 will be found by measuring the sweeps from A X to G X, deducting half the thickness of the rafters on each end. Patterns should be made for each course as it will be seen that each is struck from a different radius, shortening as they ascend to the top: 1 in the plan corresponding to 1 in the elevation and so on up. It will, therefore, be clearly understood how to frame such a roof as this when boarded or covered vertically.

To find the exact shape and size of the covering boards, take any one of the six divisions and set it off on each side of G, the point where X G, cuts the quarter circle A F, at G; produce X G, indefinitely. Now, with the dividers set off on G S, the six distances, H 1, 1 2, 2 3, 3 4, 4 5, 5 J on the elevation; and draw lines from these points square to G S. Next, again with the dividers, make these squared lines each equal in length to the dotted lines passing through G X, from T to U, and draw the curves as shown, which will give the exact length and curvature of the boards to be bent round I J. There will be six of these for each quarter circle on plan or 24 for the whole roof. If this be laid out on a cardboard sheet cut out and folded it will be found to fit exactly.

To cover this roof horizontally, all the rafters, 24 in number, must be set vertically or plumb, as B X, 1 X, 2 X, etc., to A X, and it would be best to have a finial or block at the top to receive the top ends of the rafters. In order to find the shape of the level covering boards, divide the curve Fig. 43, into 6 equal parts and draw lines from division points parallel to plate. Join A 1,

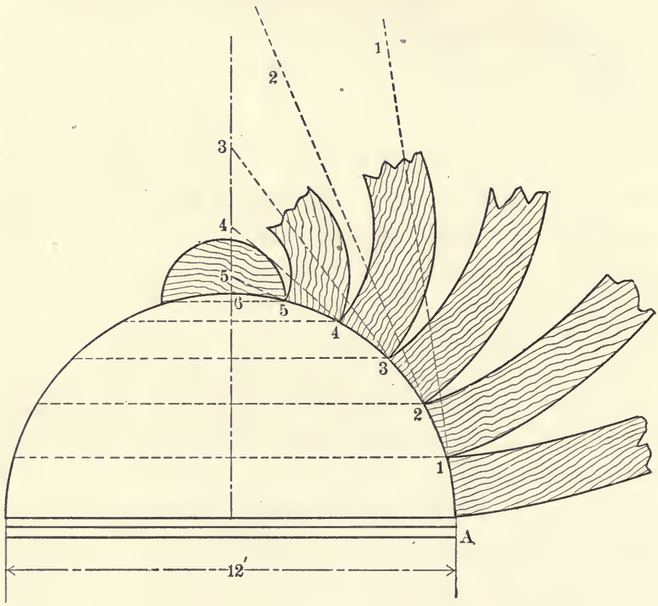

Fig. 43.

1 2, 2 3, 3 4, 4 5, 5 6, and produce these joining lines till they cut the centre line produced indefinitely. The points where these produced lines intersect the centre line will be the centres for the curves of the covering boards as represented in the engraving.

CHAPTER XVII.

To Frame a Circular Elliptic Dome.

Readers will observe that I have here treated a roof with which most mechanics are unfamiliar, and it is a pleasure for me to describe it for this reason. A C D B, Fig. 44, is the plan or outside line of the plates which measure 12' 0" x 20' 0", or the roof will be 20 feet long and 12 feet wide. Across I K R its section will be a semi-circle, as at A E B and across F K S its section will be a semi-*ellipse* (not an *oval*, as this figure is often miscalled). As there may probably be some readers who are not acquainted with the proper methods of striking a semi-ellipse, as A M' L' H C really is we will proceed to illustrate and describe the best in use.

In referring to the engraving, Fig. 45, we will suppose A B to be 20 feet long and C D 6 feet equal to the I H on Fig. 44. Now to find a curve closely resembling that of the ellipse draw the line E C F parallel to A D B, and draw A E and B F. Now divide the sides E C and C F each into five equal parts as 1, 2, 3, 4, and E and join these dividing points with the angle A, as 4A, 3A, 2A, 1A, and CA. Similar lines are drawn on the other side to B. After this is done, divide the sides AE and BF each into five equal parts and join the dividing points with C, as AC, 1C, 2C, etc.; do likewise on the side BF. Next proceed to trace the elliptic curve through the points where the joining lines intersect each other, as shown in the diagram, Fig. 45. As this method is not always applicable in the case of large

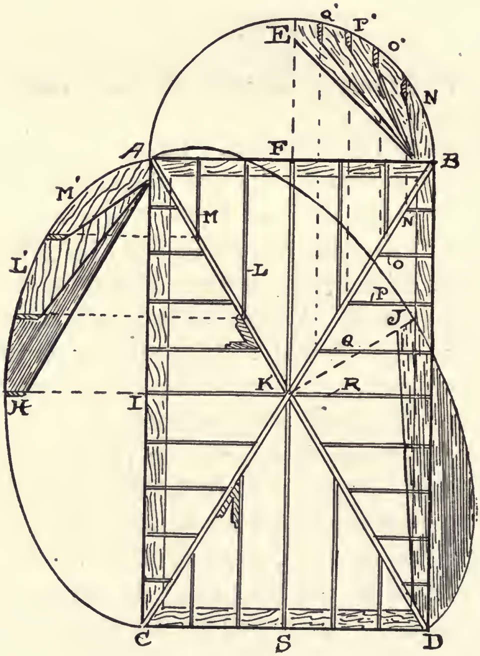

Fig. 44.

spans like on this roof I would recommend mechanics to use the trammel method illustrated in Fig. 46. The trammel is made of two pieces of grooved stuff halved together in the way denoted by the heavy black lines in the engraving. In the groove two little runners slide, and to them is loosely attached a rod as ACB in Fig. 46. The distance from A to B, Fig. 46, is equal to half the long diameter of the ellipse, or from A to I or I to

C, on Fig. 44, and the distance from C to B is the same as the height on from I to H, on Fig. 44. At B the pencil is placed, and being moved round, as it were, the

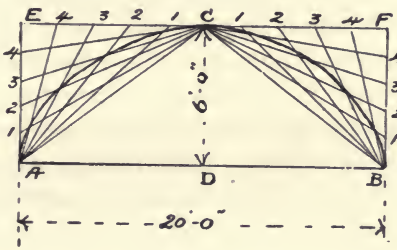

Fig. 45.

slides run in the grooves and the pencil follows and outlines the desired elliptic curve. By means of the trammel the full ellipse may be outlined. Fig. 47 gives another, but less accurate, method of obtaining this

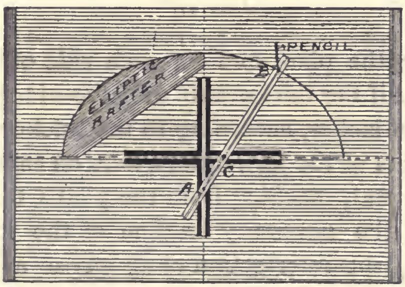

Fig 46.

curve. AB is the length, CD the height. Take a rod and set off the length AC from D on the line AB. This will give the two foci or points E and F. Drive nails or pins into these points and to them attach a string which will reach exactly to D. Now place a pencil inside the string at D and trace the curve as shown. This is a very simple way to gain an elliptic curve, but is not a very true one on account of the stretching of the string. It is, however, good enough for small curves. Where the trammel is not available *ellipses cannot possibly be accurately described* with compasses.

Having given the best methods of striking out elliptic curves we will refer back to Fig. 44. We find the cross and longitudinal or length sections to be a circle and an ellipse. Now to frame the dome join BC

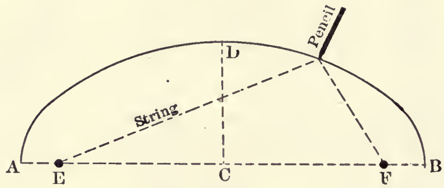

Fig. 47.

and AD on the plan, and on each side of the centre line set off half the thickness of the hips—inch, inch and a-half or two inches, according to the thickness. Next draw the seats of the jack rafters, nine on each side, and five on each end, reaching from the plates to the hips.

To find the necessary outline of the hip rafters, which, being the intersection of an ellipse and a semicircle will be also of elliptic form, from the centre K, raise up the height K J, equal to H I, and proceed to strike the curve A J D, by any of the methods described; J D, will be the outline of the top edge of the hip rafter. For the jacks draw lines from the hips on the seat lines cutting the quadrant E B in N O P Q, which will give the exact lengths of the semi-circular jacks N, on plan ; O, on section, to O, on plan, and so on up to R, which rafter will be a quadrant as E B. In the same way the two elliptic jack rafters on each side of K F, as M, and L, are found by the dotted lines. The plumb cuts will be, as usual, plumb, and the side bevels will be those seen on the plan. To those who have the time and patience, I would recommend that they make scale models of these roofs from the descriptions given in previous chapters and in this. Nothing verifies and proves the value of a system of lines like an accurate model or true representation of the actually constructed roof on a small scale, and it is my great desire to publish nothing which is not both accurate and necessary.

CHAPTER XVIII.

To Frame an Elliptic Dome With an Elliptic Plan.

At Fig. 49, the plan of the elliptic roof, let A B C D E F G H I J K L M N O and P be its shape on the outside line of the elliptic plate, cut in sweeps as shown in the engraving. In striking this plan, any of the methods which I described in the last chapter, or by the simple and accurate method which I here illustrate at Fig. 48.

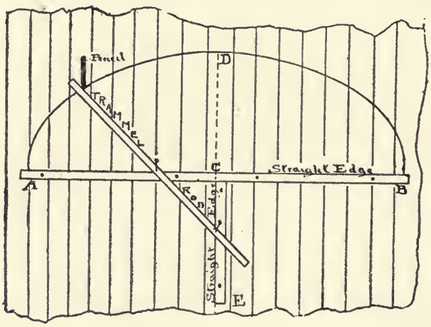

Fig. 48.

It consists of one horizontal straight edge A B, tacked on the floor on the line of the major axis or long diameter of the ellipse, and a second straight edge C E, set on the minor axis or short diameter below it. These are represented in the engraving. A trammel rod or tracer is made with the distance from the pencil to the farthest nail against the short straight edge, equal to A

C or half the long diameter, and the distance from the pencil to the nearest nail sliding against the long straight edge, equal to C D or half the short diameter. The

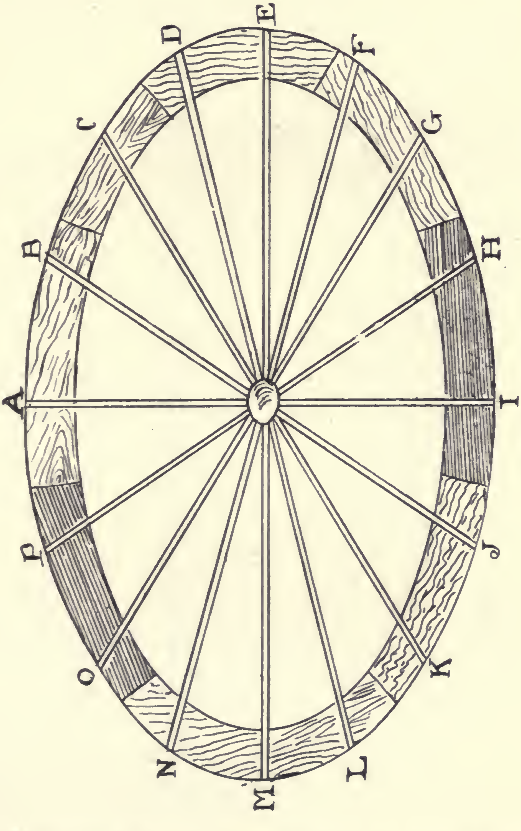

Fig. 49.

elliptic curves may, by this method, be accurately struck to the size desired.

In this dome roof I have inserted a boss in the centre to receive the top cuts of the elliptic rafters, all of which radiate from the centre to the outside edge of the plate terminating at A, B, C, D, etc. The rafters which will stand over the plan, Fig. 49, on M E will be

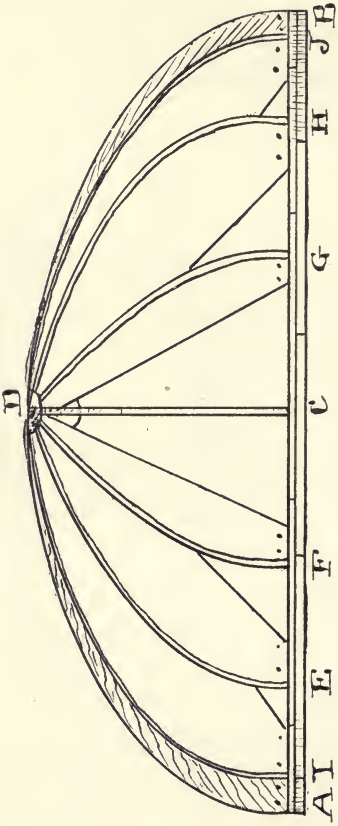

Fig. 50.

A D and D B on Fig. 50, which is the projection or view of elliptic rafters nailed in position.

Each set of two rafters, as AI, BJ, CK, DL, Fig. 49, etc., must be struck out separately with the major axis

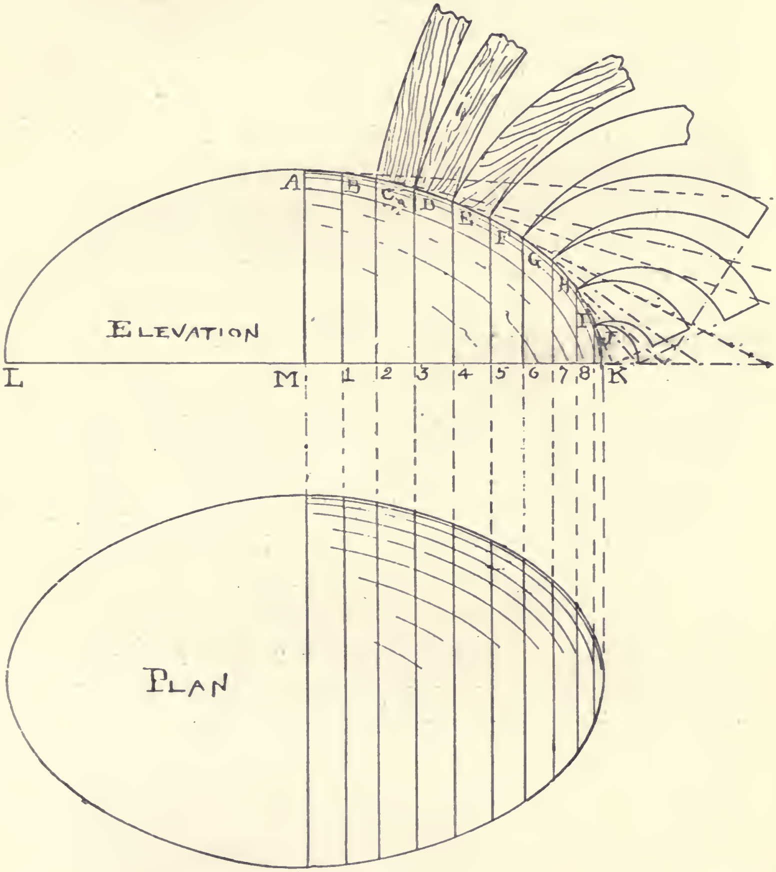

Fig. 51.

or long diameter of each, being the plan length as AI, BJ, etc., with the minor axis as CD, Fig. 50; great care and accuracy is necessary in striking out each set so as to have their curves, absolutely correct and appear as at Fig. 50 when raised.

In order to determine the shape of the covering boards or roof covering proceed to Fig. 51 and draw the long diameter LMK, also the short diameter MA, and strike the elliptic elevation of the roof LAK. Divide the quarter ellipse into ten equal divisions as denoted by A B C D E F G H I J K and let fall lines square to M K as A M, B1, C2, etc., and produce these across the plan below, to represent 10 boards bent across the rafters. To find the exact shape of these covering boards join the division points on the curve A K, and produce each till it cuts the line M K produced. The points where these lines intersect will be the centres from which the curved boards, which are necessary to bend across the rafters, may be struck in the way represented in the engraving, Fig. 51. For the purpose of fully proving the correctness of the above methods I would urge upon mechanics to make a scale model as before in cardboard of this roof, thus proving the exactness of the methods set forth in the foregoing.

CHAPTER XIX.

Framing a Circular Molded Roof Tower.

Having before described the proper methods to be followed in framing a straight sided or conical roof with a circular base of plan, in this chapter I will give readers

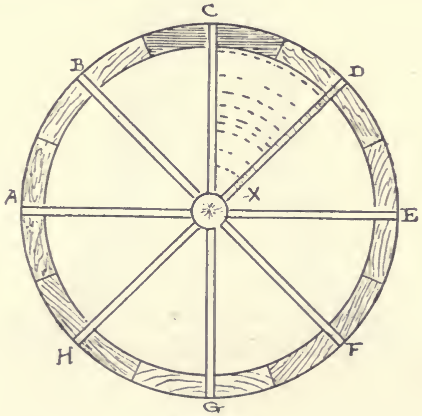

Fig. 52.

the information necessary to know in laying out and framing a roof with a molded form of rafter. As there are many of these constructed now-a-days it will no doubt be welcome to studious mechanics.

By referring to Fig. 52 it will be seen that the plate or plan is a complete circle, as A B C D E F G H, made up in two thicknesses of sweeps cut out as I have shown by the joint lines. The molded rafters (of a bell shape) are, as seen on plan, eight in number and must be made exactly to the curvature represented on the projected framing of the roof or rafters, etc., raised as seen at Fig. 53.

In order to obtain the exact flexure or curves the writer has followed the following method with much success and shaped many molded rafters to the design intended by the architect: 1st, make a laying-out floor

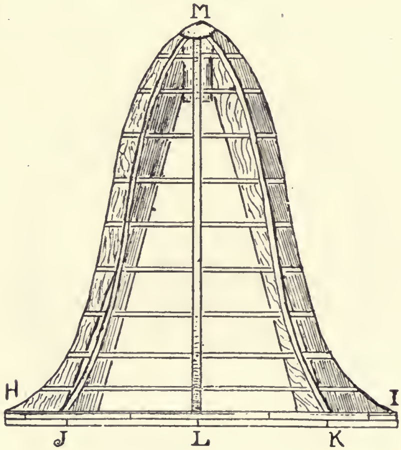

Fig. 53.

of a number of boards placed level on planks, or sweep an ordinary floor clean, big enough to lay the roof out on, and draw any base line as A B in Fig. 54; also divide it in the centre at C, and draw an exactly vertical or plumb line to it, as C D, then divide the height line C D into 12 equal parts as 1, 2, 3, etc., and draw through these lines parallel to A B, as 1 1, 2 2, and so on up to 11. Now set off the lengths 1 1, 2 2, and so on up, and trace the bell shaped curves to the desired flexure. If the architect furnish only a ¼-scale drawing of the roof, the scale drawing can be similarly lined off and the lengths taken with the scale rule transferred and relaid out on the floor, thus obtaining the curve.

When the curve is laid out on a drawing-board the pattern rafter is made by placing the planks on the lines and marking on it the length as before described and illustrated in Fig. 54, where a rafter, A D, sawn out is

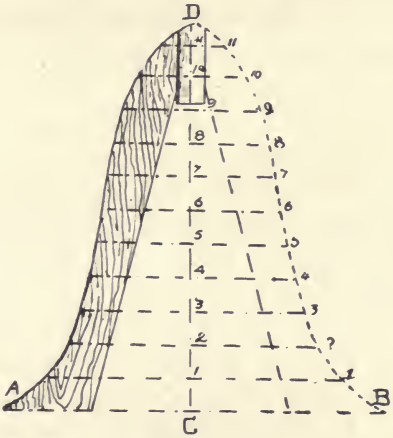

Fig. 54.

delineated on the left hand side, and the thickness of the 6-inch *boss* at D, which is inserted for the purpose of giving a better nailing at the peak, is taken from the top cut. This boss is also seen on the plan, Fig. 52 at X, and on the projection of set-up rafters, Fig. 53 at M, where it is obviously necessary in order to obtain a firm nailing for the top ends of the molded rafters. At Fig. 53 the mechanic will see how a series of circular strips or *sweeps* as they are technically termed, are nailed in, ranging from the plate to the peak. These are essential when it is intended to board the roof from bottom to top, for the purpose of nailing the boards to them.

They are sweeps or arcs of circles and struck from different radii, decreasing as they go up. This will be readily understood by studying the plan, Fig. 52, where the dotted lines represent the outside edges of the sweeps shown on Fig. 53. As there are 8 intervening spaces between the rafters, and there are 9 in the height, there will be 72 needed altogether or 8 of each kind, and they may be solidly nailed in the way indicated in the engraving, Fig. 53.

This form of roof may be covered in two ways, either vertically or horizontally. When covered vertically, the sweeps described above are inserted and the shape of the covering boards determined, in the following manner. Let A B C D E F G H I J K L M N O P on Fig. 55 be the plan of the outside edge of the circular plate, and A X, C X, E X, G X, I X, K X, M X, and O X be the rafters, all abutting against the boss X, on plan, in the manner seen at D, Fig. 54; also suppose the dotted lines on Fig. 54 to represent the outside edges of the sweeps. To determine the shape of one covering board, produce X C to U and on the line C U, taking U as centre, proceed to strike the arcs *a b*, *c d*, *e f*, *g h*, *i j*, *k l*, *m n*, *o p*, *q r*, *s t* cutting U C at the points 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Then set off on each side of the line U C, on each arc, the distances from X B on the plan, *taking the exact full length of the curve* and *not* on a straight line, each corresponding as shown in the engraving. For instance, *s c t* must be the full length of the curve B C D, and so on with each all the way up.

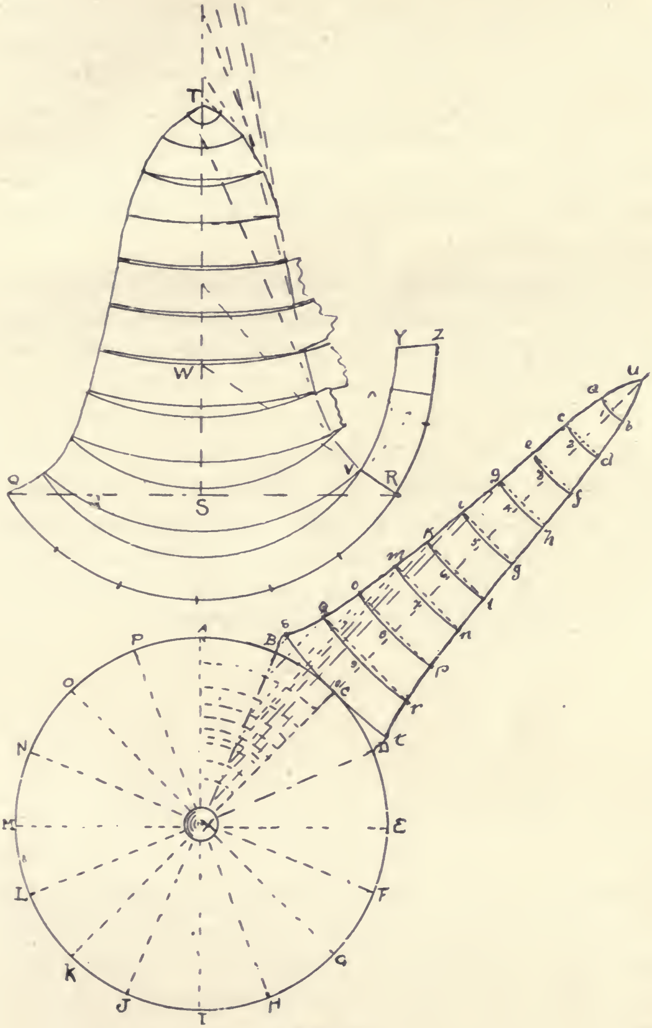

Fig. 55.

If the roof is intended to be boarded horizontally then more rafters must be inserted, in order to give a better nailing, and this roof will then need sixteen, instead of only eight, as before, see Fig. 55. To obtain the shape of the horizontal covering boards, proceed to the upper engraving and draw Q R equal to M E below, and S T vertical to it. Also set off the bell-shaped curves as shown.

To find the shape of the first or bottom board, assume R V to be a straight line, and produce it till it cuts the vertical line S T at W, then with W as centre and radii W R and W V, strike the two arcs Q R Z and Q V Y. Finally, to find the exact length of this bottom board, take any curved distance on plan, as A B, Fig. 55, and set it off eight times from Q to Z, as indicated by the marks. This will give half way round, which doubled will give entire circular covering board for the first section. By continuing this process up to the top, all the horizontal boards may be laid out.

CHAPTER XX.

To Frame a Gothic Tower Roof of Four-Centre Section.

I, here set before readers a form of roof which is fast becoming popular on account of its uniform outline.

As the section of the roof is a combination of curves,

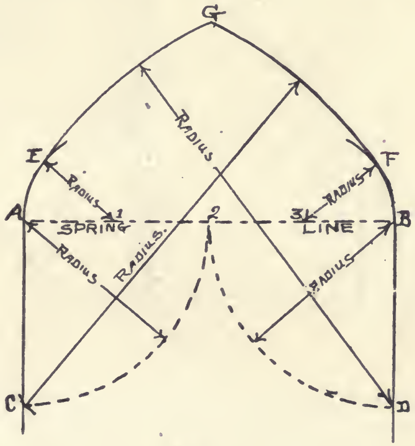

Fig. 56.

we must first proceed to lay it out. On a large floor or platform draw the *spring line* AB, Fig. 56. Divide this line AB into 4 equal parts as 1, 2, and 3. From A and B, draw AC and BD square to AB. Now with A as centre and A2 as radius strike the curve 2C, cutting AC at point C, likewise strike the curve 2D cutting BD at D. This process locates the desired centres for the different curves of the dome or tower section.

With 1 as centre and 1 A as a radius, strike the short curve, or arc A E and with 3 as centre and same radius strike B F. This gives 2 arcs, next with C as centre, and allowing the *trammel pencil* to be just *tangent* to B F at F, describe the arc F G. In a similar

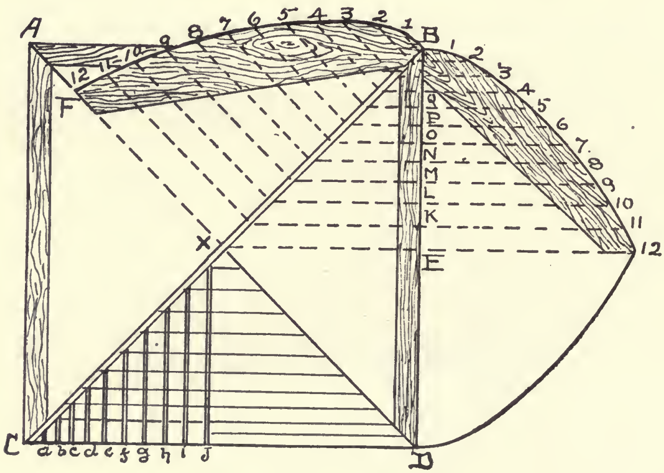

Fig. 57.

manner describe the arc E G on the left. This process carefully fóllowed out will give the exact four-centre gothic section, but it must not be followed in every plan where a roof of this section is shown, as the position of the centres may not be placed or divided off as is shown above, and a detail or layout of the roof may be necessary to determine their position. The foregoing description, however, will make the work familiar and easy.

In order to lay out the rafters for this roof, proceed to Fig. 57, and lay out the plan A B C D full size, also draw the diagonals A D and B C, the seats of the hips, with the jacks *a*, *b*, *c*. *d*, *e*, *f*, *g*, *h*, *i*, and *j*, against the hip seat C X. On the line B D, divided in half at E, raise up the gothic section line, and from this section make a paper or wood pattern rafter to the curve B 12, in the manner shown in the engraving. Divide B 12,

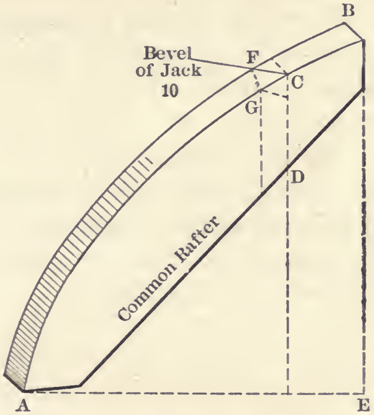

Fig. 58.

into twelve equal parts, as 1, 2, 3, 4, etc., and from each division point draw a line square to the line B E D, and produce these lines to the hip seat.

B 12, will, of course, be the common rafter standing over E X. Each jack will, because the hip rafter is on a mitre or angle of 45 degrees, be shorter as they go down from X to C, and their lengths will be as K 11, L 10, M 9, N 8, and so on down to B.

From the points where these dotted lines cut B X, draw up square to B X, lines of an indefinite length. Now, commencing from B, on line B E, take the first division 1, and set off the height from the line to 1, on the first line on the hip seat, also height at 2, 3, 4, 5, and so on up to 12. To be explicit, I would say transfer these heights from perpendiculars on B E, to perpendiculars on B X. Next trace the curve, F B, through the points 12, 11, 10, etc., and the proper outline of hip rafter will be found.

At Fig. 58, readers will see a comparatively simple method which may be followed to obtain the top side bevel of the jack rafters. A B, is the common rafter showing its upper edge. Set off rafter No. 10 from A to C, C D, being the vertical or plumb cut. Square across from the upper edge corner, from G to C, as C F, and from C D, set off the thickness of the jack rafter, 2 inches, or 3 inches, or whatever it may be. The bevel will be as shown in the engraving.

CHAPTER XXI.

To Frame a Trussed Roof of Large Span on the Balloon Principle.

That carpentry is a progressive art is a truism that the observer will not hesitate to admit, and a careful examination of the timber structures being erected in the United States to-day will impress the examiner with the fact that it is also a liberal art. This is, without doubt, one of the chief reasons why wood has not been entirely driven out of the field by its great competitor, iron, as it can be readily and economically employed where the latter material would be inadaptable. The numerous and exceedingly artistic dwellings which are erected in all parts of the country attest this, and while designing them the architects have endeavored to devise new forms of construction which might enable them to produce an effective design and at the same time be a cheap one to build. An illustration of this will be seen in the sketches which are here introduced, as they explain a unique method of balloon framing which was adopted in a church, the building being a frame structure, and having an auditorium measuring 56 feet square. The architect wished to avoid inserting the usual form of trusses and, after careful study, he devised the manner of construction here shown. Fig. 59 is the plan of the auditorium, E A K D G C I B E being the outside line. B F A, A L D, D H C and C J B are the trusses which the reader will notice do not span the roof at right angles in the way generally followed, but are placed at an angle of 45 degrees across the angle of the corner. Each of these was 41 feet on base line and were framed in the way represented in the isometrical

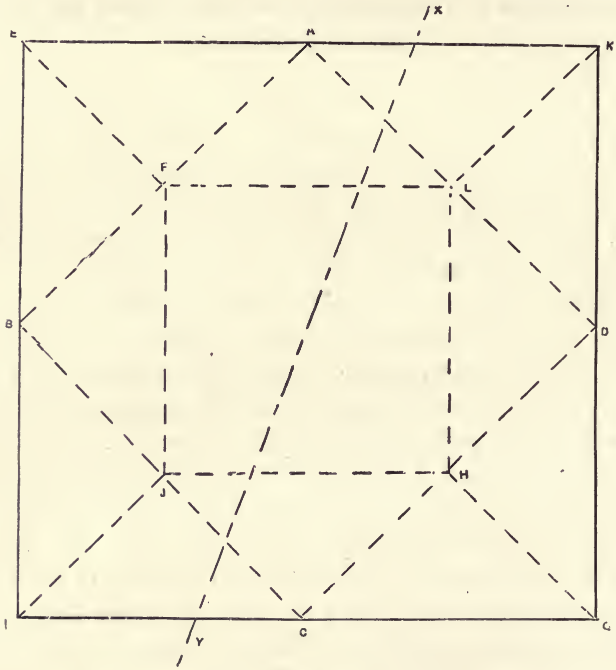

Fig. 59.

projected view (Fig. 60), without any tie beam, yet of a form statically strong enough to support the rafters and shingling placed upon it. They were then placed diagonally across the plan so that their seats formed a square, as it were, within a square. This the reader will comprehend better by referring again to Fig. 59,

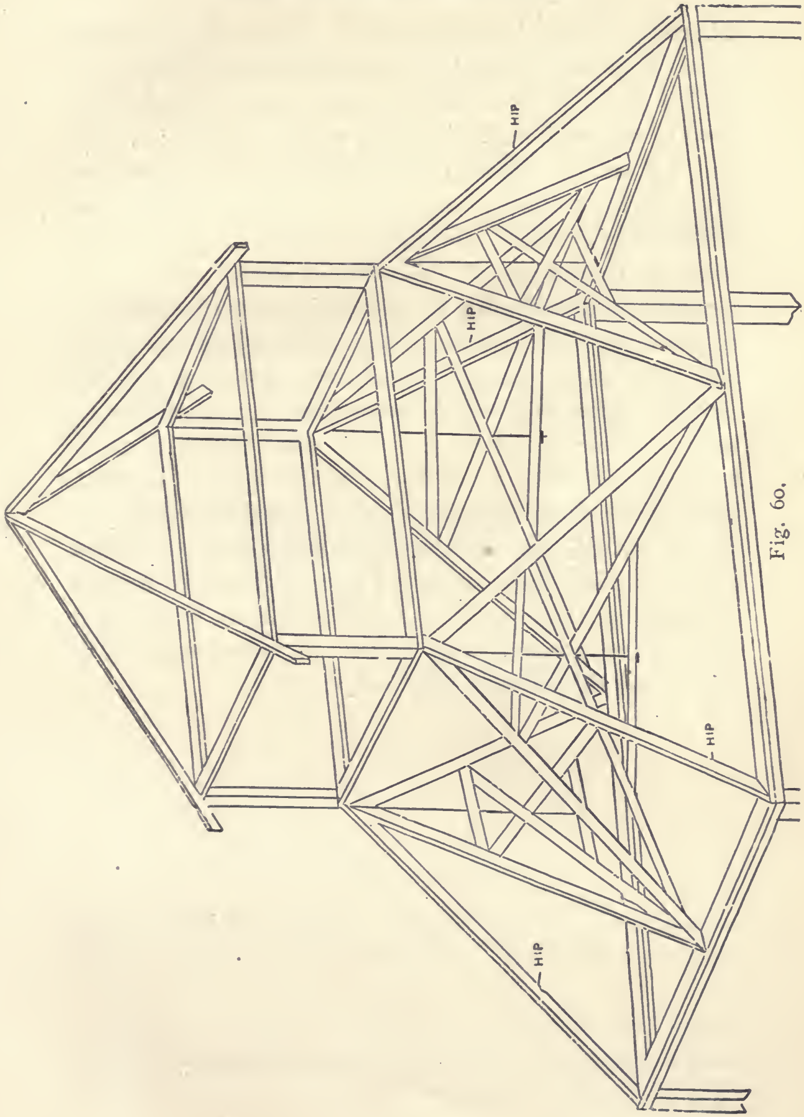

Fig. 60.

where the dotted lines A D, D C, C B and B A, are the seats of the trusses, and a close observation of the projection (see Fig. 60), will give him a perfect idea of how they were positioned. The hip rafters, E F, K L, G H and I J, rested against the trusses which support on their peaks the upper wall plate or purlin on which the ventilator was raised, and against which the jack rafters from the trusses rested. A peculiar feature of the construction, which the reader will notice, is that the principal rafter of the trusses in each plane of three, as D L and D H, in the plane G H L K, was partly a hip and partly a valley rafter at the same time, because the jacks were cut from the plates below to them and from them to the purlin above; but the sides still formed separate planes and, when covered, showed a straight surface, as G H L K, Fig. 59. Taking the whole construction as a piece of statical and economical design, it savors more of engineering than architecture, but as an uncommon piece of roof framing it is a most ingenious method of solving an old problem in a new way.

CHAPTER XXII.

To Frame a Roof of Unequal Heights of Pitches and Plates.

Having described in previous chapters roofs springing from wall plates on the same level, I will show in this the proper method to be followed in framing two roofs where the plates are at different heights and the

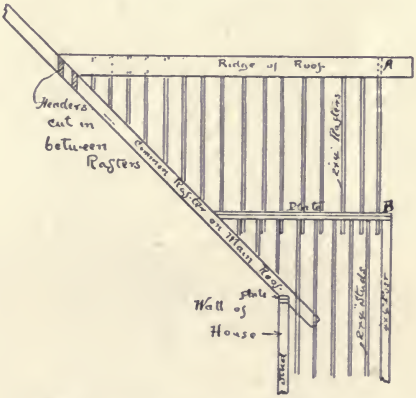

Fig. 62.—SECTION ON LINE A B.

roofs at different pitches. These roofs, to those unused to them, appear very difficult to frame, but are really not so.

Fig. 61 will give readers a full conception of the timbers forming the two roofs as they will appear when "raised" or set up in their permanent position. It will

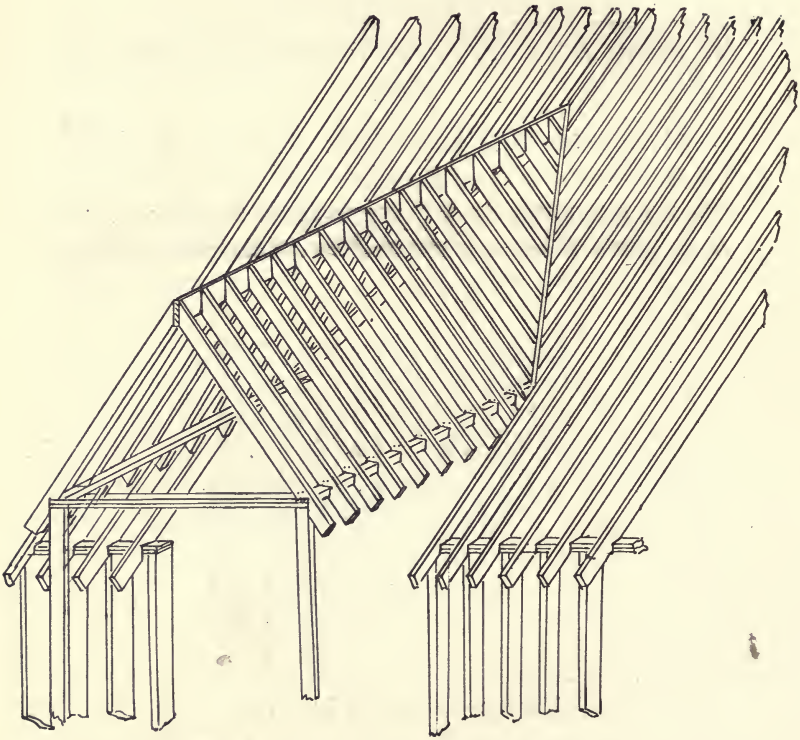

Fig. 61.—Roof Timbers when Raised.

be noticed that the wall-plate of the projection or bay is about four feet higher than the plate on the main wall of the house, also that the rafters are cut on different pitches.

If the reader cannot clearly understand this I would refer him to Fig. 62, which is a sectional view of the roof when raised through the line A B, on the plan of

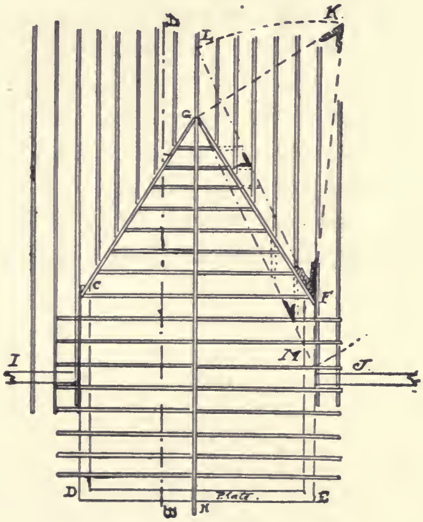

Fig. 63.—PLAN OF ROOFS.

roofs, Fig. 63. Here the different levels of the plates will be seen and another view of the rafters and stud wall of the projection. As the timbers are all marked very little description is necessary.

Concerning the methods to be followed in finding the lines for this form, it is as follows: C D E F, Fig. 63, is the plan of the extension plates, I and J being the plates of the main house wall. G C and G F are the seats or plans of the valleys determined by the intersection of the two peaked roofs. To find the exact length of these valleys raise up square the pitch G K. Set off the height G K equal to A B Fig. 62, and join K F, which line is the exact length of the valley rafter as seen at Figs. 61 and 62, also the length of G C.

Next, to find the lengths of the jack rafters on each side of the valleys set a pair of compasses to the line K F, and with F as centre cut the line H G L at L and join L F. Now if the jacks from the ridge line H G be produced to the line L F their exact length will be given with the side or top edge bevel. To obtain the length of the jack rafters on the main roof, the feet of which nail against the valleys, draw G M parallel to L F and the lengths of these jacks will be thus found.

CHAPTER XXIII.

To Frame a Hip and Valley Roof of Unequal Pitch.

Figure 64 is the projection of the roofs completed, and it will be noticed that they are of different pitches and widths. A B C D E F G M H K I J, Fig. 65, is the plan of the building. A B is a gable end, and A N is the length of the common rafter; also D E is a gable end. D O being the length of the common rafter each has a ridge L N X and P O Y. The main roof is hipped,

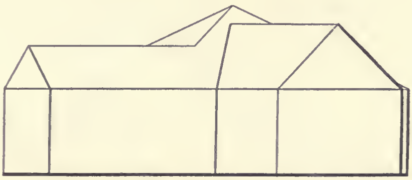

Fig. 64.

having four principal hip rafters with jacks. The intersection of each of the L's on the building with or rather in the main roof gives three valley rafters and creates the framing problem which is to be worked out.

Proceed to lay out the plan of the plates, hips, valleys and ridges as shown on Fig. 66, and join I G and H Q giving the peak R; also draw the dotted lines K R F and M R X in Fig. 65. To obtain the length of the main hip rafters square up from R and set off on the square line the pitch height R S equal to E T. Join

H S, which will be the exact length of the hip rafter, with the bevel S for the top cut and the bevel H for the bottom cut.

To find the lengths of the jacks set a pair of compasses or a rod at H and with H S as radius sweep the

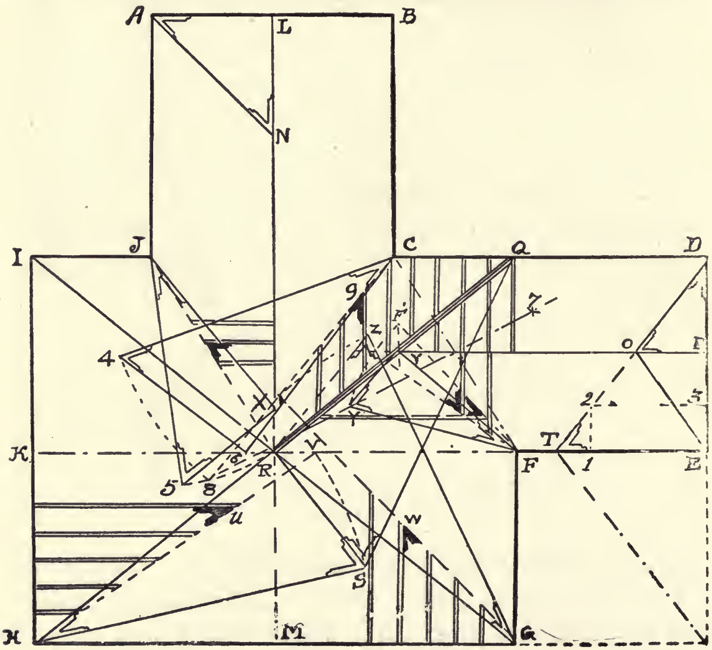

Fig. 65.—LAYOUT OF RAFTERS.

arc S V. Join V where the arc cuts the line R F and H, also draw the jack rafters square to the plate K H until they reach the line V H, and this line will determine their length and the bevel U will be the cut across the top of each against the hip, that at I being the plumb cut. Reverse cuts are made to go against the hip I R and G R, from the plates K I and G F.

To find the lengths of the jacks placed on the plate G M H, proceed to raise up from R square to G R, the pitch R Z; join Z G and with G as centre and radius G Z sweep the arc Z X, cutting M R N L in X; join X G. Set off the jack rafters in the manner shown, reach-

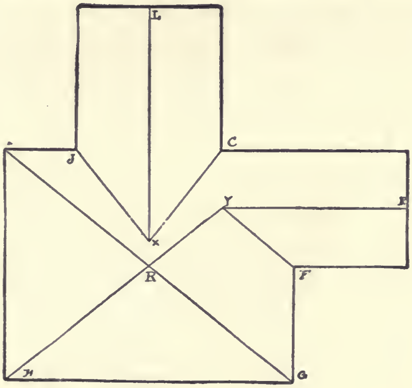

Fig. 66.—PLAN OF ROOF.

ing from the plate G M H to the line G X and their lengths will be thus found. The bevel W will be the cut across the top edges of jacks in getting the cut to fit against the hip. It will also be the bevel reversed on the opposite side to fit against the hips standing over Q R and R I.

In framing the valleys to stand over the seats X C and X J, first find out where the ridge will penetrate the main roof. This may be simply done by setting off on the line E T, the half pitch height L N and drawing out square as 1, 2. The point 2 will be the point where the ridge L N will enter the main roof. This must be transferred over to cut the ridge X; and J X, C X will be the seats of the valleys.

To find the valley rafters, square up from X, which will be the line X 5, on it set off the pitch N L, and join J 5 which will be the exact length of the valley rafter with the top and bottom bevels as indicated on the diagram. It will be here seen that I have prolonged one valley from X till it cuts the centre line of the main roof and, at the point where it cuts, raised up the whole pitch of T E, as 6 4. This is done for the purpose of determining the lengths of the jack rafters, and is necessary to find the angle. C 6 F is the angle. To find the short jacks reaching from the hip Q R to the valley C X, join C F and divide it into two equal parts as 6 7. Now with C as centre and C 4 as radius, sweep the arc 4 8, cutting 7 6, produced at 8 and join C 8; next draw the jack rafters from R Q to the dotted line C 8, which will be their lengths and the bottom cuts across the top edge of each jack, nailing against the valley rafter 6 C, will be the bevel 9.

The jacks from the ridge L N X to the valley J X, are found similarly by setting the compasses to radius J 5 and sweeping the arc cutting the line X R; then by joining this point with J by the dotted line seen to the left of the valley, the jacks may be drawn as before.

For the valley F Y raise up, square from Y, the pitch Y Y equal to P O, and join Y F for the length of valley. The jacks are found by the process described before and the bevels are clearly seen. Each hip and valley rafter should be gotten out separately to avoid confusion, and the diagram closely studied as the system is simple and easily understood.

CHAPTER XXIV.

To Frame a Roof of Unequal Lengths of Rafters.

Let A B C D in Fig. 67 be the *square* plate or lower plate, which has short, or *curb* rafters supporting a *circular* plate, E F G H, on which rests a drum, or short cylindrical tower as E C D F, Fig. 69, topped by a roof

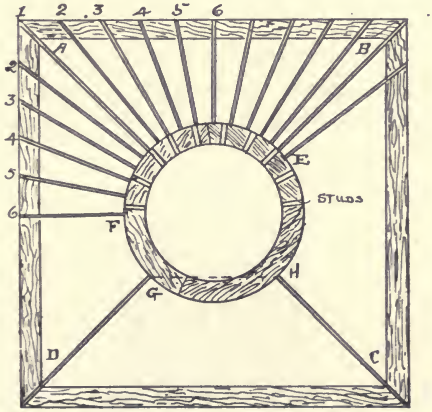

Fig. 67.—Plan of Plates and Rafters.

with curved rafters. By referring to the plan, Fig. 67, it will be seen that the seats of the rafters will be of different lengths, increasing from the centre, or number 6, to the corner or hip rafter 2, and that this occurs on all four sides of the square plate. As the seats are of different lengths the rafters will also be of different lengths, though they have the same *rise* or pitch, as X Y in Fig.

68. In this figure the different lengths of rafters will be distinctly seen decreasing in size from the hip or angle

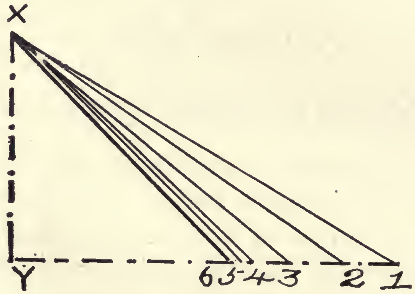

Fig. 68.—Different Lengths of Rafters.

to the centre of the plate, this occurring on each side, which will necessitate 8 sets of five rafters, cut with right and left hand bevels on the plate, also one set of

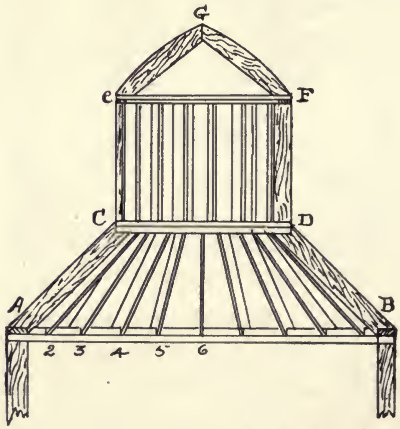

Fig. 69.—Projection of Roof and Drum.

4 with square cut on plate, as number 6. Each succeeding rafter will have different top and bottom bevels,

and require great care in laying out, so as to cut the timbers without waste, so that it would be wisest to lay out and cut them in sets, one for each side. The top and bottom cuts, as represented in Fig. 69, are also notched to fit over the plates and thus prevent their slipping; this will also demand care in laying out, because each notch will have a different bevel. The gothic roof on the drum may be struck out to the curve shown and rafters cut out. As all the rafters are the same length, they can be sawn from one pattern, and set up in the manner which I have already described.

CHAPTER XXV.

To Frame a Roof with Pitched Ridges.

The following roof of an unusual kind will be found of value to those carpenters who live in the country or whose duty it is to construct barns, or other special buildings, where great room is required in the roof or attic.

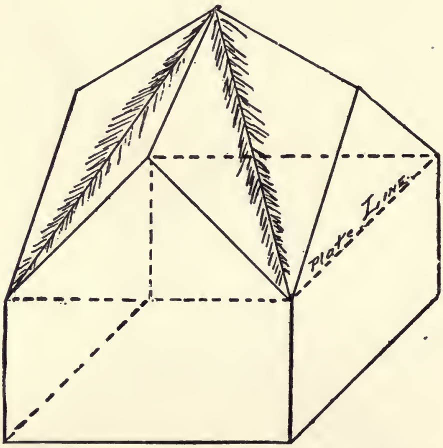

Fig. 70.—General Appearance of Roof.

The engraving, Fig. 70, is an isometric view of the roof, and as will be seen it consists of a roof of four gables on a square plan, with four valleys and four ridges which rise on a pitch from the peaks of the gables and terminate at the peaks of the valleys, giving the effect as shown. The rafters of the gables are half or mitre pitch, or twelve and twelve on the steel square. The peak of the valleys represented in Fig. 71 is 4 feet higher than the gable peaks so that the ridges rise on pitch in the manner shown in the cross section Fig. 71, thus forming a very peculiar and unusual form of roof.

In order to frame this roof in the simplest manner proceed to Fig. 72, and let A E B H D C be the plan of the roof A F, B F, D F and C F, being the seats of the valleys. E F, H F, G F, and I F, being the seats or plans of the hips. To find length of valley from F

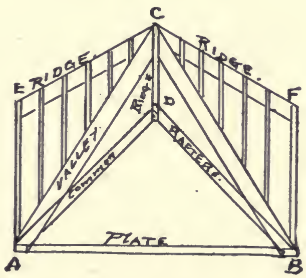

Fig. 71.—VALLEYS, RAFTERS AND RIDGES.

square up at F, A J, equal in height to A C Fig. 71, and join J C, Fig. 72, for the lengths and bevels of the four valley rafters. Now for the eighteen jack rafters the author has found it most convenient to develop the roof in order to prove the accuracy of the layout; therefore on C G D, erect one gable to stand over C G D, as C K D. From D, make D M, equal in length to C J, and K M, equal in length to the ridge E C, or C F, Fig. 71. Divide off on K M, Fig. 72, the jack rafters and draw them parallel to K D, in the way illustrated at

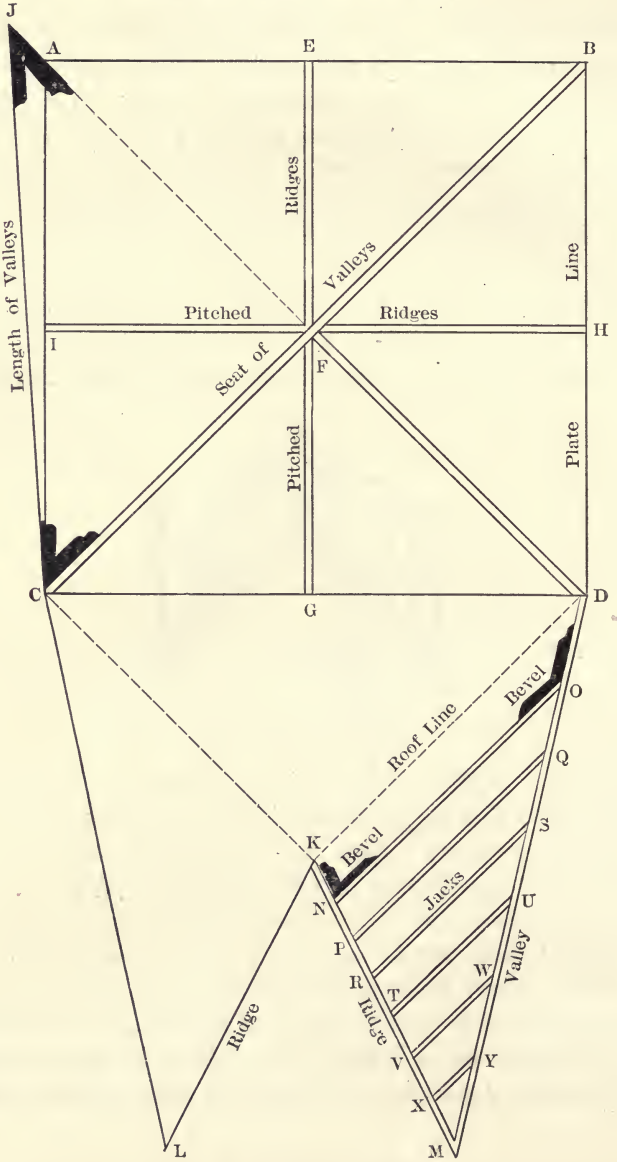

Fig. 72.—Layout of Roof.

Fig. 72, as N O, P Q, R S, T U, V W, and X Y. The bevels at O and N, Fig. 72, will be the side bevels against the ridges and valleys, being reversed for different right and left sides, the down or vertical cut of the bottom ends of the jacks nailed against the valley sides will be as the pitch of the valleys and the top cuts as that of the gables or mitre cut. To prove the accuracy of the methods, first draw the engraving on cardboard and then cut out as follows:—Cut out the whole plan, A E B H D M K L C A; then make a slight cut with a pocketknife from C to K, and from K to D, also across C G D. Fold over the development until K is over G D M, is over D F; C L over C F; and L and M joined together, are over F, with the ridge L K over G F.

CHAPTER XXVI.

To Frame a Round-House Roof.

Assume the roof to be semi-circular in plan as represented in Fig. 74, and to have a pitched roof with a ridge, the pitch being half, or 12 and 12 on the steel square, as seen at D G F, Fig. 74, where the lengths of the rafters and bevels are delineated. A B C and D E F, are the gables on the plan Fig. 74 seen on the elevation Fig. 73, with windows and doors in same. In order

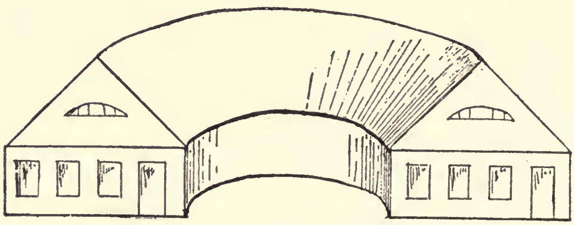

Fig. 73.

to find the length of the common rafter simply raise up from E, Fig. 74, the pitch or rise E G and join D G. As the outer plate line A X F, is much longer than the inner plate line C Z D, more rafters will be required so as to form a sufficient support for the roof boards and covering. For this reason an extra rafter from the plate line A X F, to the ridge B K I E must be inserted between each abutting rafter so as to equalize the spacing and obtain a stable roof. The proper way to find the shape of the roof boards is seen at the bottom side of Fig. 74. Divide D H into 10 equal parts, or more if desired, then with O, as centre and O 1, as radius, describe a curve, similarly describe curves from D, 2, 3, 4, 5, 6, 7, 8, 9 and 10, which will of course bring the boards up to the ridge line. Now take the distance

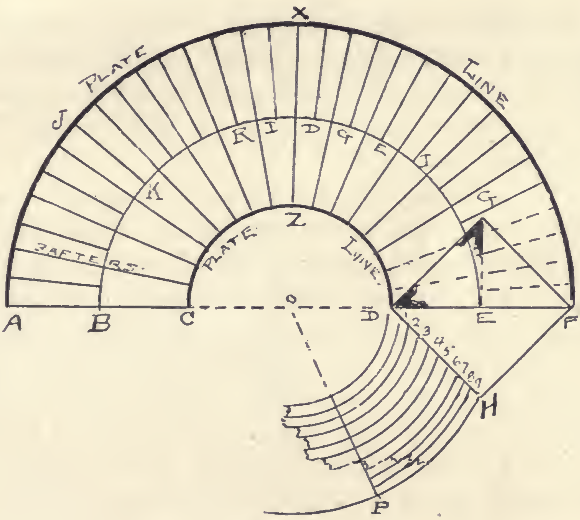

Fig. 74.

from E to I and set it off from H to P, the centre of the rafter at I, and this will give the lengths of boards for one section. A like method can be followed for covering the outside slope of the roof. This roof is of a very rare kind and is only found on railroads where locomotives are stored or on large estates for barns or outhouses.

CHAPTER XXVII.

Framing a Cantilever Roof.

In answer to a letter requesting me to illustrate and describe a cantilever roof, I submit for the benefit of all students of carpentry the following design for a roof of this description, which will be adaptable either for a large shed or station.

The engraving, Fig. 75, shows a transverse or cross section of the shed, which may be any length desired, the width (covered) shown is 48' 0", at a scale of 1/8 inch = 1 foot. If the width be reduced half, timbers half the width and thickness given here will be sufficient. The height to under side of straining beam is 13' 0", to ridge 26' 6". The construction of this building is very simple and is fully illustrated by the drawing. It consists of a series of concrete footings about 3 feet or 4 feet square, placed on sand or hard clay 24' 0" apart, measuring from centre to centre across; and 10' 0" apart, measuring from centre to centre, longitudinally or lengthways. On top of these footings is set a good blue or granite stone mortised out to receive the bottom ends of the posts or uprights. These details constitute the foundation.

The frame superstructure primarily consists of the series of 10" x 10" yellow pine square posts, which are tenoned at top and bottom ends, at the bottom to fit into the bottom stone and at the top to receive the

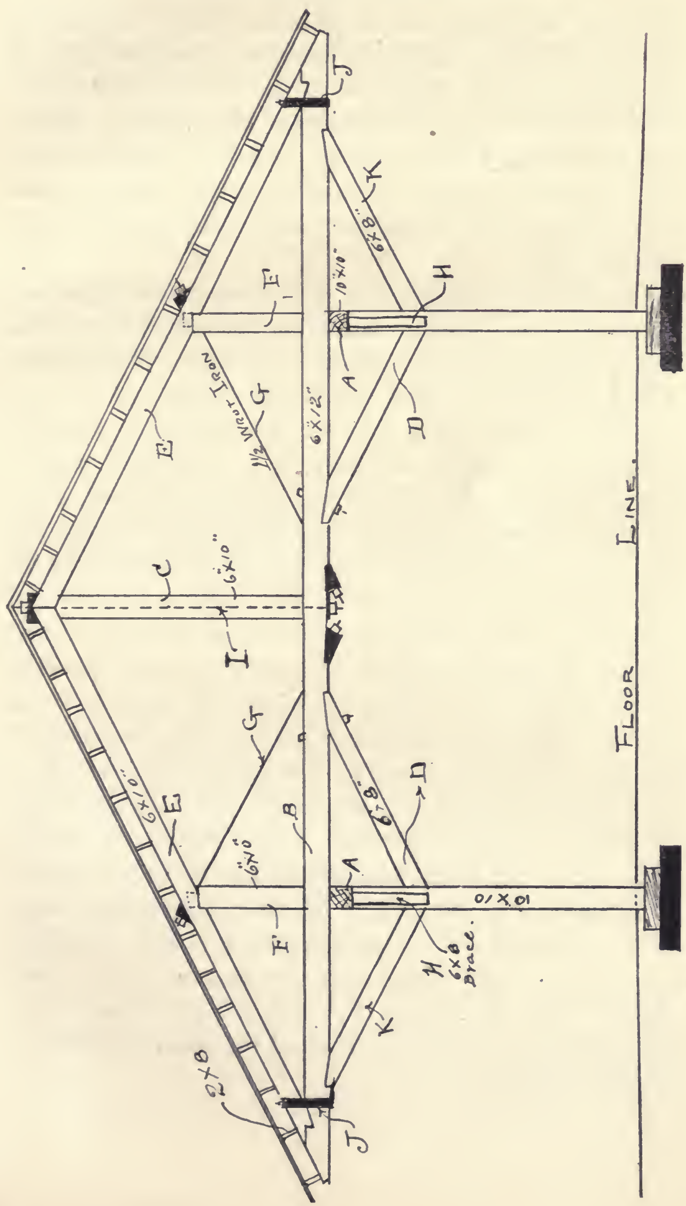

Fig. 75.—Design and Details of Cantilever Roof. Scale 1/8" ÷ 1 Foot.

10" x 10" stringer beam or plate A. This longitudinal plate or stringer is mortised to receive the top ends of the posts and the top ends of the diagonal braces H, which stiffen the whole structure lengthways. When constructing this shed the *posts*, *braces* and *stringers* should first be framed, put together, raised and temporarily braced across before commencing to frame the *trussed* roof.

Before commencing the latter a close study should be made of the different constructive details of the roof and the lengths and forms carefully noted and studied out in order not to spoil any of the timber.

The first important detail is the *straining beam* B. This stick should be procured 50' 0" long, laid out and wrought as follows: First, the proper position of the *stringers* A, 24' 0" between centres is laid out on the under side, also laid out and gained for the braces D. Then directly in the centre of this distance on the top side of the beam, the position of the *king tie* C, is laid off and distinctly marked. Directly over the position of the *stringers* a mortise to receive the short 6" x 10" *posts* F is made on both ends, also the opposite ends are notched or gained out for the feet of the *principal* rafters E, in the manner shown, about 2" down in the beam. Next the *principal rafters* E, are mortised out for the short posts, cut to the exact length as given, to the top bevel and notch required to fit into the straining beam. It is also bored out for the wrought iron rods and bolts G. The *straining beams* are likewise bored for these irons. The *short posts* F, and *braces* D are finally framed with the usual *tenons* and the *truss* is ready to be put together.

In doing this the proper way to proceed is to first set the straining beam B, then to insert the tenons of the *short posts* F, into their mortises, next the *king tie* C, and finally the principal rafters E. The vertical bolts I, and washers are next inserted and the straps J put on. This operation must of course be gone through on each *truss*, and the whole number finished before commencing to raise them into their permanent position on top of the stringer beams AA. The raising can be done with a good gin pole or derrick. When the trusses are set vertically on stringers AA, to form the appearance seen in the engraving, directly over the posts below, each one should be well braced with 2" x 4" joists to prevent it from being blown or knocked down. Each truss should also be set perfectly plumb sideways. If desired, the outer braces KK may be omitted and the wrought iron rod G inserted to counterbalance the overhanging portion of the roof. The space inside the braces may also be filled in with ornamental scroll work, either in iron or wood. In regard to the strains on the different timbers I would say that the *straining beam* B is in tension, the *braces* K and D underneath to the posts are in compression. The *principal rafters* are in compression. The *king tie* C is in compression and the *purlins* bear a lateral strain across the fibres. The bolts are wrought iron. The washers and plates cast iron. *Straps* are of wrought iron ½" x 2". This roof may be safely covered with shingles, or metal shingles, or tar paper.

It will be noticed that I have given in this description a full written and detailed description of the construction of this roof and "mode of procedure" necessary to be followed in building it. The years which I

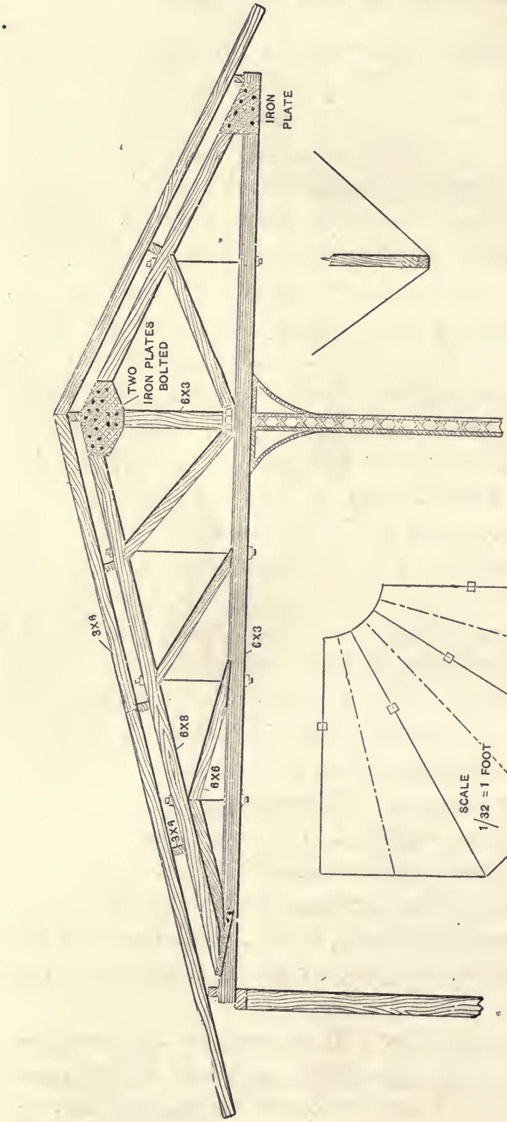

Fig. 76.—Cantilever Truss.

have studied construction have taught me that much detailed information is never superfluous in conveying accurate mechanical practice to others.

The truss illustrated at Fig. 76 was designed by Walter P. Rice, C. E., of Cleveland, Ohio, for the roof of the grand stand at the baseball park in that city, and reflects great credit on him for the economical manner in which he disposed of the constructive details in such a way as to leave an unobstructed view of the field. As will be seen on reference to the plan the portion of the roof where the cantilevers were employed covered the portion on the corners which was contained in the two sides placed at right angles, and had a post been placed under each truss the view of the field would have been much intercepted. To avoid this he suspended the intervening trusses shown by the dotted lines on the plan on iron rods which were carried over those trusses resting on the posts, thus leaving the space below clear for the spectators to see the players. These trusses are but slightly different in form from those in ordinary roofs, though the static conditions are changed on account of the cantilever form. The drawing will explain to readers its form and show how judiciously and economically the pieces were proportioned, also how the engineer, realizing by calculation that the greater part of the vertical strain would necessarily be exerted on the front columns, increased the efficiency by using iron posts of the diagonal lattice pattern of the proportions shown. The idea is an excellent one and worthy of the high reputation of its designer. It need scarcely be added that the entire workmanship of the whole construction of the stand, mostly timber, was done in the most creditable manner.

CHAPTER XXVIII.

To Frame a Roof with an Elliptic Plan and Straight Ridge.

Readers will find in this chapter a roof which is of unusual shape and entirely different from the forms generally found on ordinary buildings, and though this form of roof is not by any means original, I have never yet seen its *lines* or laying out published, even in the most advanced works on carpentry or building construction. I have no doubt, therefore, that the advanced student of framing will find in it something worthy of his attention.

Coming then to a consideration of our roof we find that its plan or plate as seen at Fig. 77, is elliptical, as 0, 1, 2, 3, 4, 5, 6, 7, etc. The length or major axis of the roof plan 0 20 is 16 feet, and its width on the minor axis is 8 feet. The ridge is 8 feet long. The 21 rafters radiate, and are spaced 2 feet on centers on the wall plate and are similarly divided up on the ridge. The rafters 0*d*, and 20 *b*, on the plan are A B, and C D, on the elevation above and each line, as 1 *c*, on plan is represented by a sloping line of the elevation. I would here state that each line as delineated simply indicates the centre line of each rafter so that the measured depth and thickness must be placed to the right and left sides of this line.

The dotted lines to the left conveying the points on

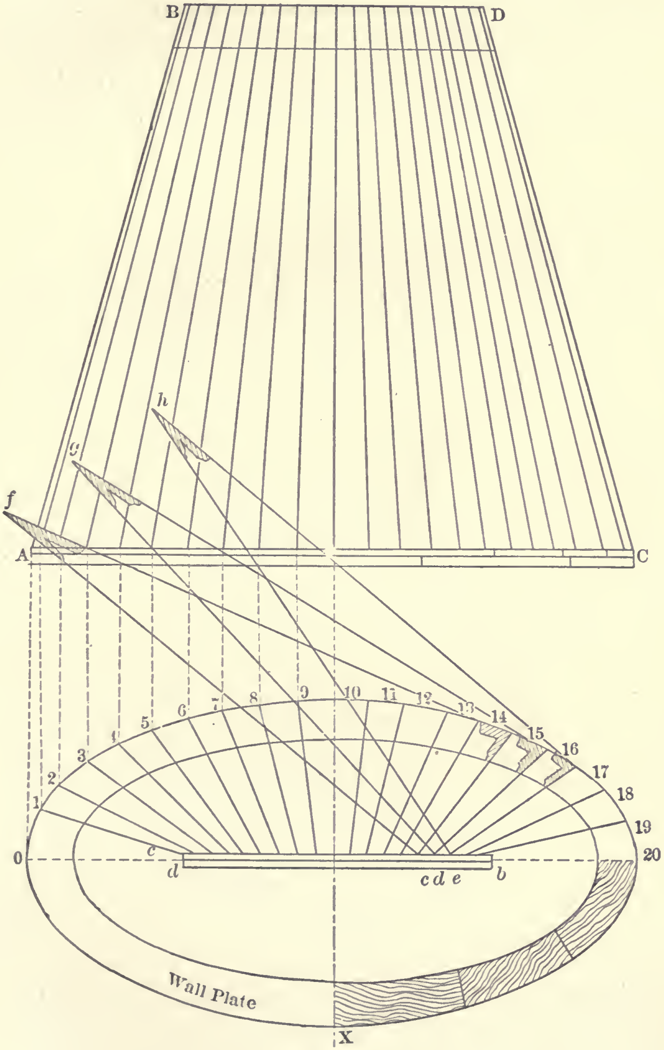
B
D
h
g
f
A
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0
c
d
c d e
b
Wall Plate
X

Fig. 77.

the plate on plan to the same on the elevation, will show how they correspond, and I would draw similar dotted

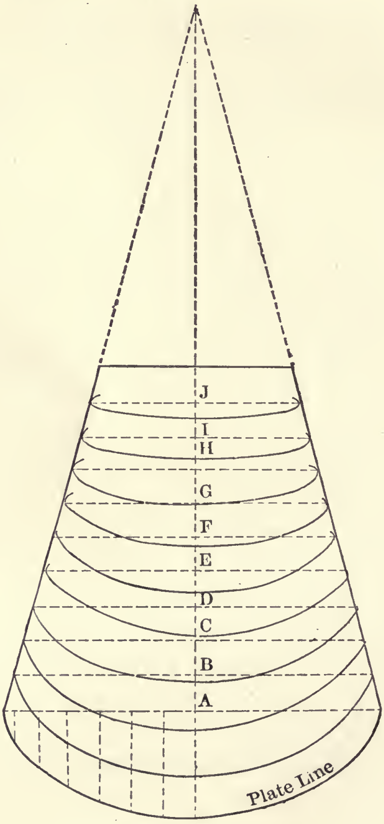

Fig. 78.

lines from the ridge on plan to the ridge on elevation where it is not liable to confuse the diagram and render it difficult to understand. The plan shows the seat or *plan* of each rafter, and the elevation its exact position when raised.

In order to obtain the neat length of each rafter a long and tedious method must be resorted to. This

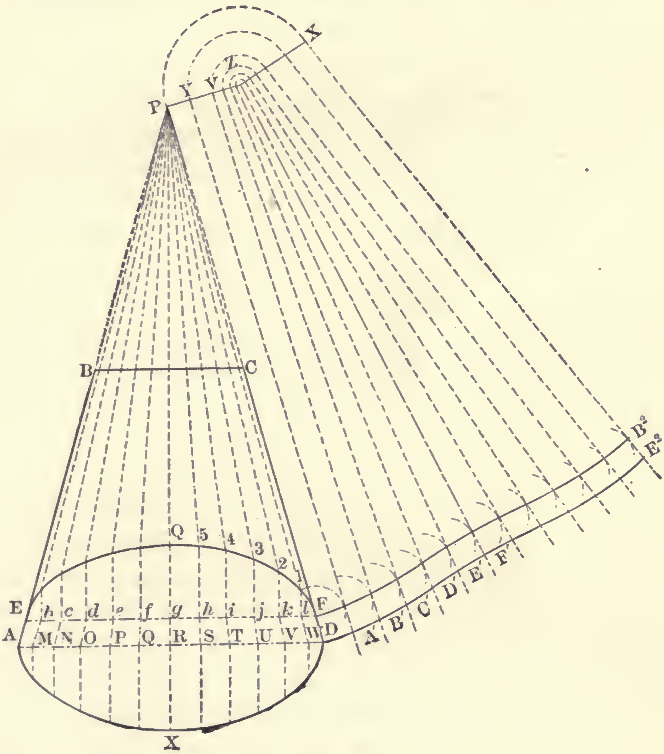

Fig. 79.

consists in raising up on each seat from the ridge at right angles to the seat, the full pitch of each rafter on a perpendicular line from the major axis, as *c f*; *d g*, and *e h*. Then join *h* 16, *g* 15, and *f* 14, on the periphery or plate, which will give the neat length of the rafters which will stand over the seats *c* 14, *d* 15, and *e* 16, with their required top and bottom bevels, represented in the engraving. This same process must be done for all the rafters to the right of the center line from 10 to 20; and a similar set must be laid out for the left side on the bottom, to space round from 0 to x. In a like manner the set from 10 to 0 will require to have a duplicate set to be spaced out from x to 20. The bottom bevels at the plate and top bevels at ridge will likewise be of a different cut for each rafter, and will be right and left handed for opposite sides. The sides of the roof will be twisted but not ungraceful, and the laying out will be found to be very slow and tedious, requiring great care, close attention and accuracy.

Coming now to the manner of covering this roof, I would state that this might be done in either of two ways: First, by boarding it vertically; or second, by boarding it horizontally. If the first method is adopted every second rafter may be omitted, and elliptic sweeps corresponding to each ellipse as the roof diminishes to the top, will require to be gotten out and nailed in from the plate to the ridge. These will need to be sawn out to the several sweeps seen in Fig. 78, which will each require to be struck from each major and minor axis, according to their diminution as they decrease in width from A to J, at Fig. 78.

When the sweeps are found the diminishing covering boards will be almost similar to the centre lines of the rafters, as laid down at Fig. 77, the widths of the top and bottom ends being equal to those shown on the plan, and the length or height equal to the lengths of the rafters.

If it be the preference of the carpenter to cover his roof horizontally I would recommend him to follow the method which I illustrate at Fig. 79, where A B C D is the original elevation of the roof and A D the major axis of the plate, E F being the major axis of the top edge of the first semi-ellipse covering board. A D being the major axis of the bottom edge. To obtain the covering boards produce E B and F C to P, and divide the semi-ellipse E Q F, into twelve equal parts. Join each division point with P, and draw from each down at right angles to E F, cutting E F at *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*, *l*. With the centre P, through *b*, *c*, *d*, *e*, *f*, etc., draw *b* M, *c* N, *d* O, *e* P, *f* Q, *g* R, *h* S, *i* T, *j* U, *k* V, and *l* W, cutting A D, in the points M, N, O, P, Q, R, S, T, U,V,W. From these points draw lines down perpendicular from A D, cutting the semi-ellipse A X D. Now to obtain the curve of the covering board which will bend over A E F D. From P draw P Z, square to P C, and make P Y equal to *l* 1, at elliptic curve. Make P V equal to *k* 2, and so on up to *g* Q. Next with F as centre and F 1 as a radius describe the arc at F, and from Y, at top, draw Y A′, tangent to the arc. Similarly from V, and with a similar arc draw V B′, and so on to Z F′. Draw through the points where the arcs are tangent to the lines to obtain shape of top curve for covering board. When the centre point is reached, describe the semi-circle P X, at top and proceed as before. Next set off the distance F D, down from the curve F B^2 which will give the curve for the bottom edge. This process must be followed out for every board to the top by laying out the minor and major axes of each ellipse at horizontal line, as seen on Fig. 78, so as to get them the right shape. All boards should be thin so as to bend round the ellipse and be very carefully and accurately laid out. To retain the nails for slate or shingle a double thickness of boards may be laid on.

CHAPTER XXIX.

Church Roof Construction.

It has often been said that, "there is nothing new under the sun," and, judging by the continual reproduction of old, well known and comparatively simple details of building construction, it is positively refreshing to come across something which is out of the ordinary, or which shows inventive and constructive skill. I have no doubt, therefore, but that those readers who have an eye to progress and the development of new constructive details of carpentry will welcome the unusual form of trussed roof which I illustrate, and which, as far as I can learn, has never before been so arranged.

To commence, I would state that this roof covered the auditorium of a small chapel, about 50 feet long and 20 feet wide in the clear of the walls.

The roof might be placed among the "open timbered" class, though it is not entirely open, inasmuch as only half of its construction is seen from below, which will be seen by referring to Fig. 80, the cross section of the roof, showing its construction in its entirety, and which, with Fig. 81, is explained as follows: A, A, are the principal rafters, which are constructed of two pieces of yellow pine. The bottom piece is curved on the soffit side and joined to the bottom end of the upper straight part by being dowelled and bolted from the upper side, the 1 inch dowels being on the top and bottom

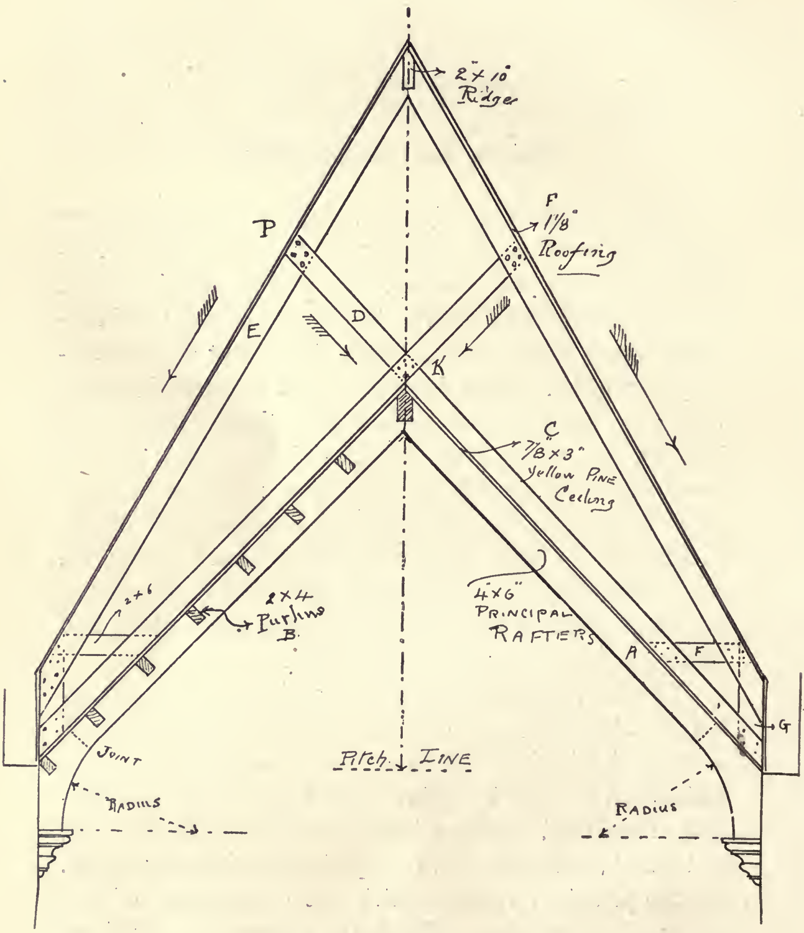

Fig. 80.—Cross Section.

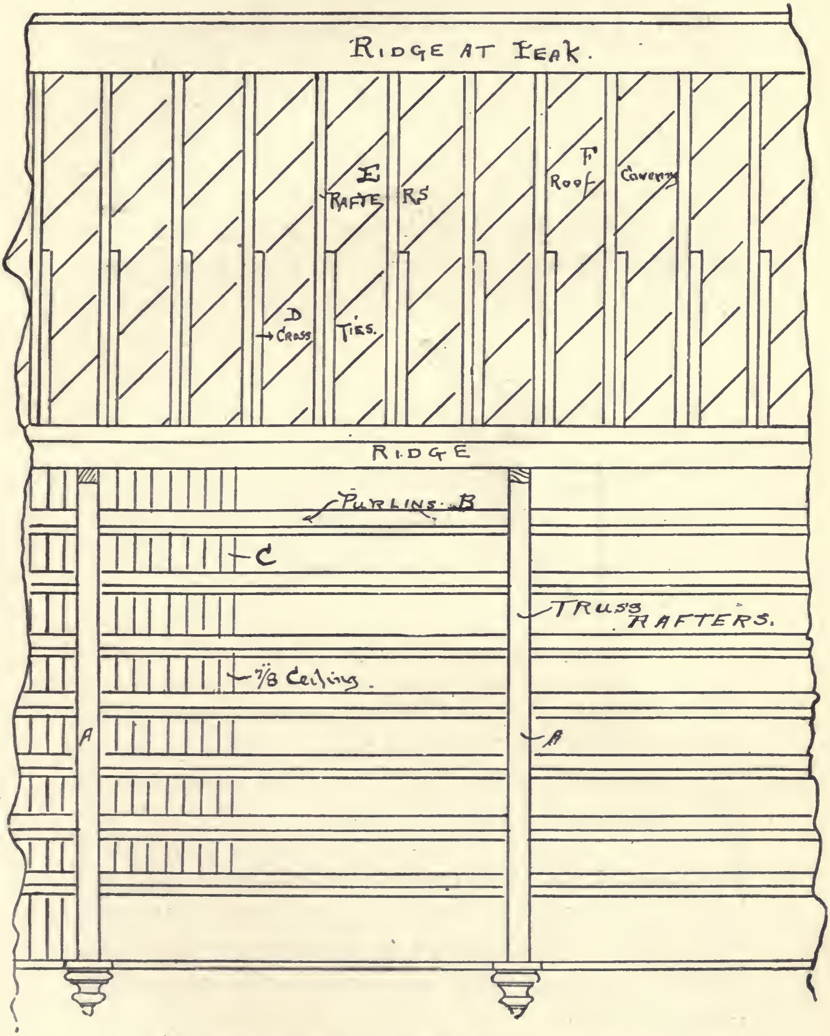

Fig. 81.—SECTION ON CENTRE LINE.

sides, and the ¾ inch wrought iron bolt, being in the center. The bolt is inserted in much the same way as a handrail screw, namely, by boring the center of the face of the joint and mortising out a slot from the upper face to permit the nut to sit down in the thickness of the timber; all this I illustrate at Fig. 82, which is a projectcd view of the bottom half, showing the joint on the radius line, with the oak dowels and ¾ inch securing bolt. Though this form of joint is not by any means *original,* I would recommend it as a very good form to

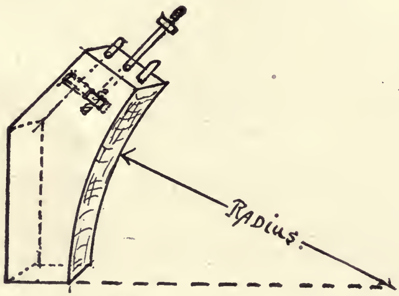

Fig. 82.—METHOD OF MAKING JOINTS.

follow, because, if the bolt be well greased before being placed in the holes, it forms a very excellent concealed tie. Care should be taken to have these bolts free from rust, as the corrosion is very liable to affect the wood. From observation and experiments made with nails I am pleased to find that iron or steel corrosion does not impair the strength of wood to any dangerous extent, as the nail or bolt continues its destruction within itself, without communicating the disease to the wood which encompasses it.

Referring back to Fig. 80, these principal rafters

A A, will be found to be notched out at the peak or upper end to receive the ridge, the top edge of which comes fair with the top edges of the principal rafters. The purlins B, seen in Figs. 80 and 81, are notched into the sides of the principal rafters so as likewise to be flush with their top edges, which will be seen to the left of the engraving. On the top edges of these purlins is laid 2½ inches matched and V edged ⅞ inch ceiling laid face side down, to a close joint, the butt joints being broken on the purlins, thus rendering them invisible from below.

From this up a rather unusual form of roof construction is adopted Reference to the feet of the high pitched rafters will show that they do not rest on any wall plate in the usual way, but are bracketed so as to be self supporting on two cleats, one set vertically and the other horizontally. The cleats being solidly spiked to the sides of the *Cross ties* rendering them permanently fixed. The cross ties support the high pitched rafters at their upper end by resting on the point K, thus forming from K to P, a sort of modified cantilever. These resist a double pressure which I denote by the directions of the arrows in Fig. 80. The high pitched rafters are spaced 12 inches on centers and each is provided with a *cross tie* or lower rafter, which of course are similarly spaced, lying with their bottom edges on the upper side of the ⅞ inch ceiling which is nailed on the purlins. These ties are toe-nailed at intervals into the purlins, so as to secure them firmly, and tie the whole roof together. The outside roofing under the slate is laid diagonally as represented at Fig. 81. Roofs of this description will require to be laid out full size in

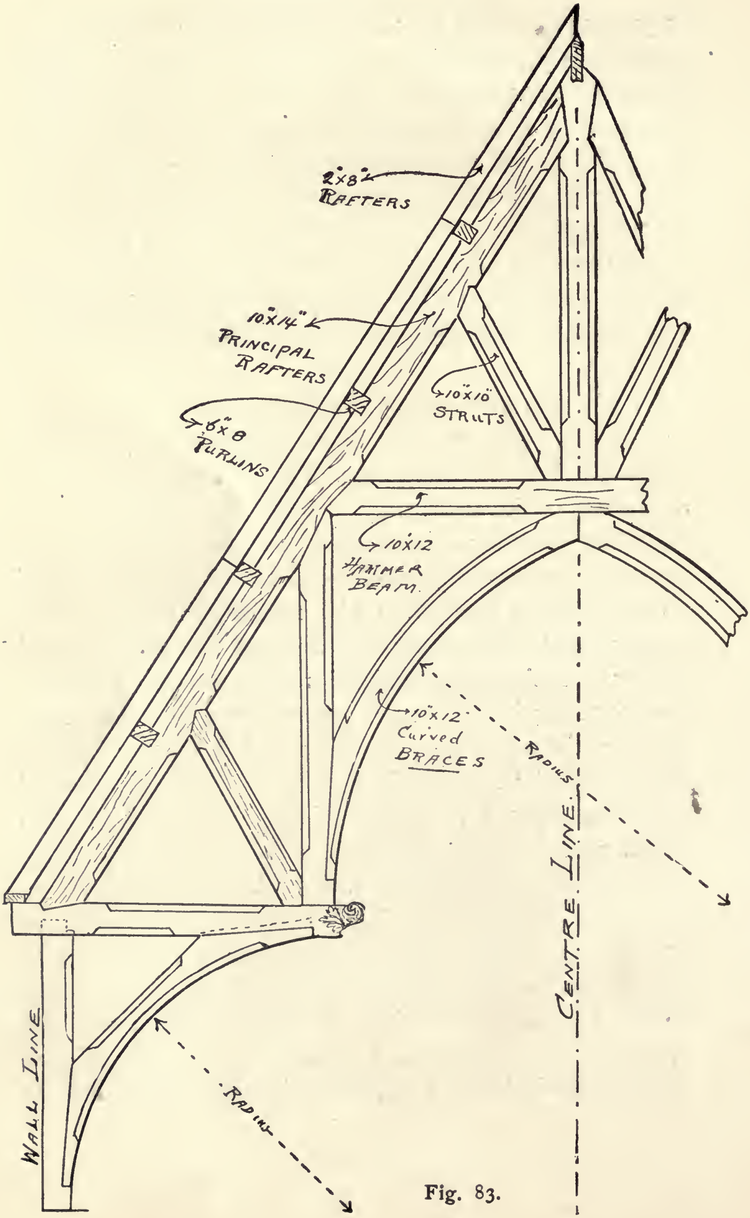
2"x8" RAFTERS
10"x14" PRINCIPAL RAFTERS
6"x8 PURLINS
10"x10" STRUTS
10"x12 HAMMER BEAM
10"x12" Curved BRACES
RADIUS
CENTRE LINE
WALL LINE
RADIUS

Fig. 83.

order to get all the joints exact, and the timbers framed to their neat lengths. I would in conclusion advise readers to make a close study of this roof and endeavor to evolve new ideas from what it suggests. I am of the opinion that there is no limit to the direct application of the cantilever to all descriptions of timber framing, and a careful examination of the qualities of timber, combined with a judicious placing of the constructive parts, will aid in producing new ideas in modern carpentry.

The following description of a very fine specimen of a gothic trussed roof will be found very interesting by those carpenters who make a study of constructive framing inasmuch as it embodies some features not usually found in roofs of this class. I feel sure, therefore, that it will be appreciated. The roof is in the city of New York and is one of the best examples of American carpentry done lately.

Reference to Fig. 83, which is an elevation of half of one of the auditorium trusses, will convey a general idea of these details which are, of course, the main parts of the construction. There are in all thirteen of these of 32 feet span, with two of larger span which have for their seats the diagonal lines of the transepts as A B, Fig. 84, where I show a sketch outline plan of the roof with the seats of the trusses which were spaced 8 feet on centre. Those lines marked T were the trusses. Ridges being on centre lines of the plan. Especial care was necessary in laying out the diagonal trusses as I will explain further on.

Now as to the construction of the transverse trusses we will proceed to analyze one, as the thirteen were exactly alike, so that a full description of one will explain how all were built, so referring back to Fig. 83, readers will see that the roof was made up of two 10 x 14 *principal rafters* 28 feet long into which were framed from the soffit side or under side a 10 x 12 hammer beam, 10 x 10 suspension timber and two 10 x 10 *struts* on

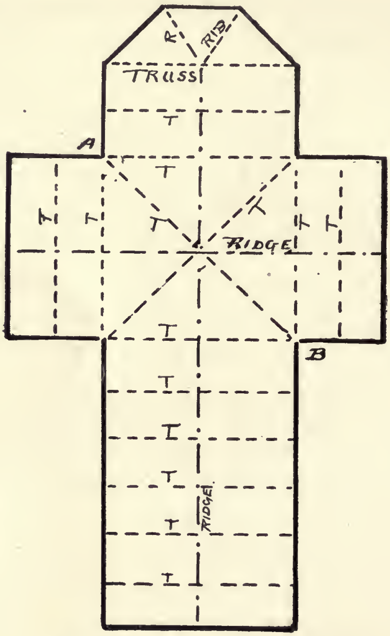

Fig. 84.—PLAN OF ROOF TRUSS.

each side respectively. The foot or bottom end of each *principal rafter* was gained and tenoned into an 8 x 10 bracket which rested on the wall and was supported by an 8 x 10 upright and a curved brace or *strut.* The centre of the *hammer beam* is also supported by a curved brace or *strut* which is gained and tenoned into the *sus-*

pension tie and is also suspended by a centre *king post*, which completes the constructive members. It is scarcely necessary for me to say that a large force of skilled mechanics were employed on this roof as the different members required a great deal of skilled working and handling especially as the roof was of yellow pine timber finished with the smoothing plane and sandpapered for varnishing. In order to comprehend this I would ask readers to observe the projected view of the principal rafter which I illustrate at A, Fig. 85. Here the *mortises* and *gains* for the *strut braces* and hammer beam are shown together with the tenoned ends, top and bottom, also the 2 x 3 gains sunk in on the back or top edge.

In addition to this the lower arrises were stop chamfered down ⅞ of an inch on each face; so that skilled readers will appreciate the amount of framing involved on twenty-six timbers of this kind.

The curved *struts* B, Fig. 85, also involved much skilled labor, as it would be obviously impossible to make a timber of this curvature of one piece of timber, and even were it possible to do this the stick would be weak on account of the short grain which must occur if it were gotten out of one piece of timber. It was therefore decided to build these pieces on the "*laminated*" system; or in simpler words, to build it up in thicknesses, bending each thickness on a curved mold to the desired curvature shown at B. This was therefore done by steaming the pieces before bending, then allowing them to cool and afterwards gluing and nailing them together to make up the whole thickness. When dry the outer right and left faces of 1⅛ stuff were glued and

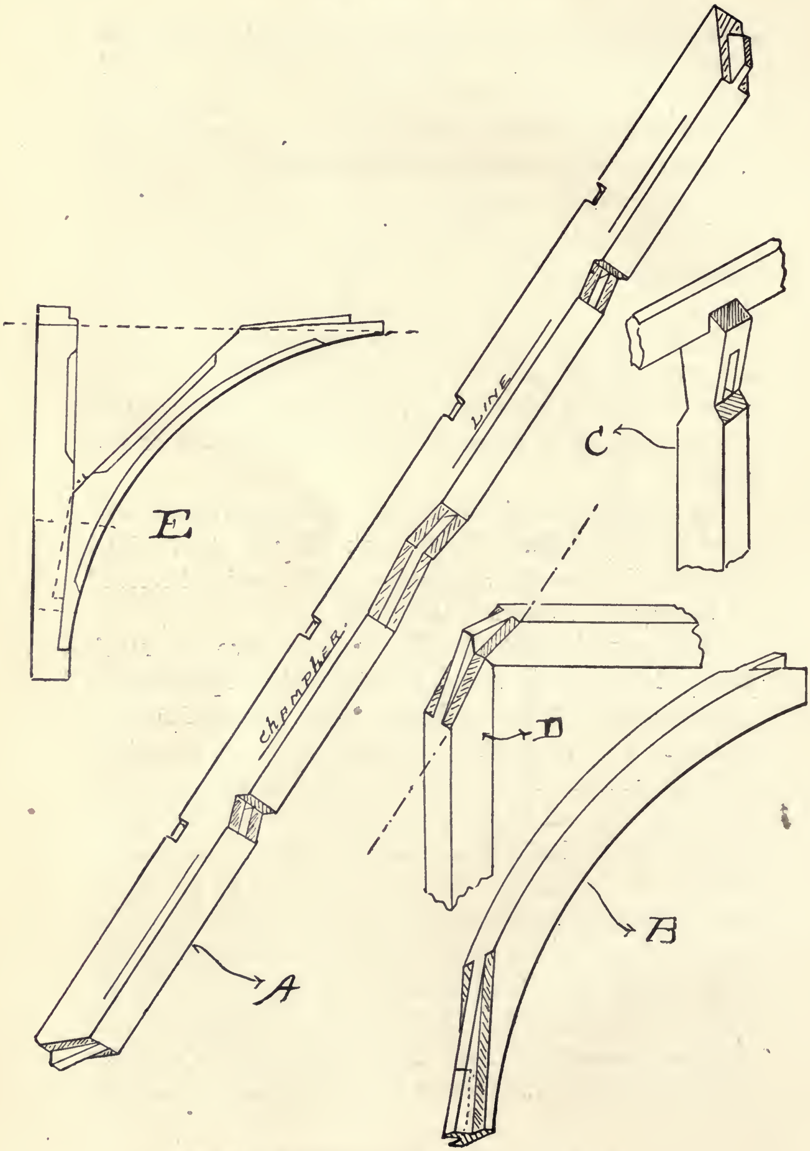

Fig. 85.—Constructive Framing of Roof.

nailed on, thus giving the whole piece the appearance of a solid timber. After the completion of the building up process, each piece was laid out and framed to fit in its place, as represented at Fig. 83.

C, Fig. 85, is the framing of the head or upper end of the *king post or king tie*, as it is sometimes termed, with the slot for the ridge cut out on top. As will be seen, it is mortised and gained out on both sides. D, Fig. 85, represents the proper framing of the *straining* or hammer beam and the suspension tie, and E the side view of the lower curved brace and vertical *wall post*. I would here state that this curved brace was also built up by the *laminated* process as described above.

The lines for this truss were laid out on a large temporary floor of smooth boards and each truss was framed and temporarily put together on the floor on the lines of the lay out and afterwards the pieces were carefully numbered and marked for right and left, so that they could be readily found when putting each truss together permanently before raising. I would also state that it was bored for the bolts, one of which was placed at every joint, the axis line of the bolt being square to the face of the joint, as shown at E, Fig. 85. Long suspension bolts passed down through the king post and suspension tie, so as to sustain the horizontal timbers and prevent their sagging, also to put the whole truss in compression. The very long joints were provided with two bolts and all were 1¼ inches thick and provided with plates and washers.

In raising the trusses each was entirely put together, bolted and raised with an 80-foot gin pole, windlass and triple sheave block tackle. The bottom section as E was not raised and placed until the main upper portion was raised on the plates. The upper construction was then raised from the plates and the section E set on the stone corbel. It will thus be seen that the short bottom horizontal beam with its supporting upright, both rested directly on the wall which resisted the oblique thrust of the principal rafters. In concluding, I would state that the panels of the truss were filled in with tracery and the ceiling above the rafters paneled out, making in all what is to my mind one of the handsomest open timbered roofs in the United States.

CHAPTER XXX.

Bow Truss Roofs.

In the construction of timber roofs to cover large areas where an open, clear space underneath is of the most importance, I have been much impressed lately with the fact that a *bow* or curved form of truss with a lattice or diagonal bracing is the lightest and most economical. For this reason I have deemed this subject worthy of a chapter and now place before readers some practical information relative to bow trusses and their construction.

These trusses, as far as I find from inquiry, can be very cheaply and rapidly put together and when properly built are capable of carrying a great strain and give a clear unobstructed area under them.

To illustrate the foregoing I will refer the reader to the illustration, Fig. 86, which is the elevation of one of twelve bow or curved or laminated trusses forming the roof of a riding academy in the City of New York, and is, I believe, one of the most recent and original of this form in the East. The walls of the arena of the academy, in the clear of the span measure 108 feet, and each truss has a bearing of 2 feet on each wall, which makes its entire length 112 feet, as shown in the engraving. Each truss is built up as follows:

A mold for bending the bottom curved planks of the lower chord A, Fig. 86, about 25 feet long, was constructed of stout plank brackets, spiked to the floor in the way which I represented in a previous chapter and on these brackets each piece was bent and curved to the radius represented, namely 105 feet. On the back of the first sprung thickness or piece a second thickness was bent and nailed, each thickness breaking joint to half the length of the piece under, so as to give the pieces strength and rigidity as a whole piece, this method

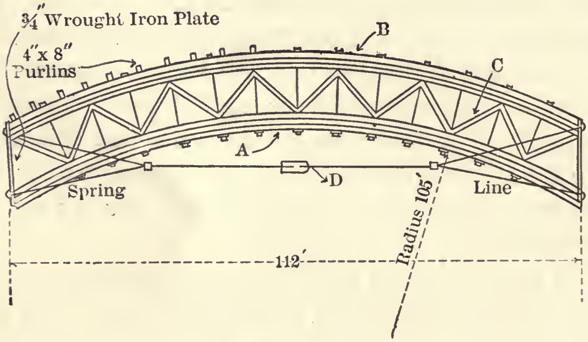

Fig. 86.

being followed till the entire depth of the lower chord, namely about 8 inches, is completed, the bending boards being 8 inches wide and ⅞ of an inch thick, taking nine boards to make up the depth.

When completed the curvature of the upper chord was formed to a radius of 117 feet and the upper chord built up in the same manner.

When this was done the two chords or more properly "laminated wooden arcs" were placed on the floor in the position shown at Fig. 86, and 8 x 8 inch diagonal braces of yellow pine were fitted in between the soffit of the upper chord and the extrados of the lower as seen, the soffit of the upper chord being first divided into fourteen equal parts, and radial lines drawn to the center, marked on the edge of the lower chord to determine the exact thrust points of the braces, which the practical mechanic will see is absolutely necessary. I would here state that this system of "laminating," or building up in plates or thicknesses is very old, so that there is really nothing original in the foregoing except that the work was done on the floor and then raised, as a whole completed truss, but the method of sustaining the entire truss in its arched form by the insertion of the "tension rod," without having recourse to any outside buttressing of the wall is, as far as I know, original. This 1½ tension rod of wrought iron with sleeves, pins, plates, and turnbuckles is the whole sustaining power of the truss. It is made up of six pieces, the two on each end passing through the center of two 10 feet long, ¾ inch wrought plates which stand vertically and receive the full thrust of both the upper and lower chords. It will be noticed that only three thicknesses of laminated boards are shown on this engraving, but it is made to a very small scale as my desire is to show the principle and method in as small a space as possible.

When the braces were fitted in and properly abutted end to end, the entire truss was bound and tightened with 1 inch wrought iron tie bolts with washers and nuts, and finally the tension tie put in, the chords being bored to receive it. When together, each truss was raised with a gin pole, horse and tackle.

Figs. 87 and 88 represent two different details of a roof for a building designed for a public market, and as readers will observe it is also a laminated truss roof, but

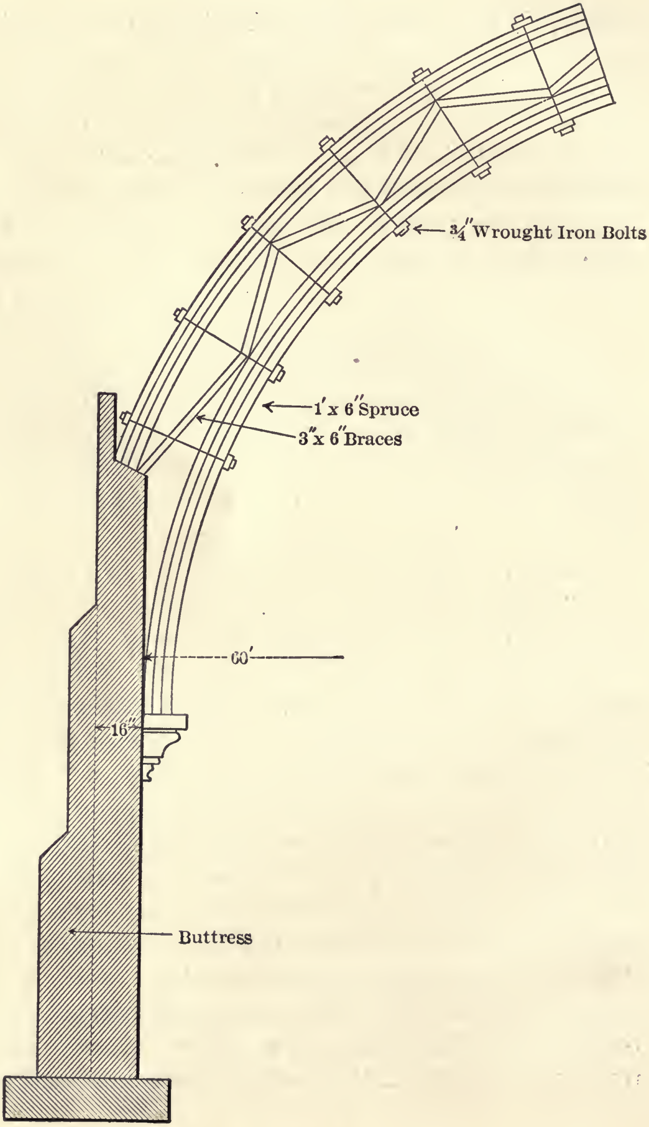

Fig. 87.

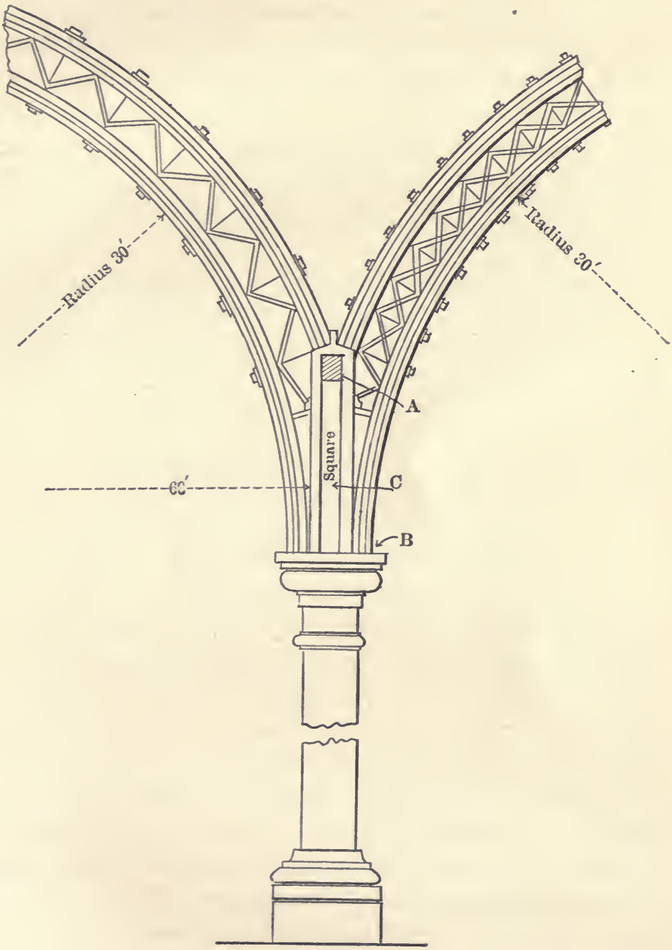

Fig. 88.

instead of being of a segmental form it is semi-circular, thus avoiding the use of the tension rod shown in Fig. 86. These trusses were made up of three 1 ½ inch thicknesses of laminated timber in each chord. The span between the columns and walls measures 60 feet, and each truss is extremely light, being with the columns and buttresses spaced 10 feet on centres longitudinally, with 3 x 8 inch purlins, 3 x 6 inch braces and ¾ inch wrought iron bolts.

Particular attention is called to the unusual form of intermediate line of cast iron columns B used in this building on which the chords of the trusses from both sides rest in perfect equilibrium, each column being braced longitudinally by diagonal braces C which are framed into the 6 x 8 inch plate A, and rest on the impost of the column B.

I sincerely regret that it is not possible for me to give larger details of this interesting timber structure, as it is an excellent model to copy or to design from by modifying some of its details to suit any one requirement, especially as I have introduced between the chords of Figs. 87 and 88 several methods of bracing which vary in strength, the intersecting diagonal bracing on the right side of Fig. 88 being of greater strength than that on the left side, and the spacing here being different from that in Fig. 87, and so on as the designer requires. In closing let me warn carpenters who may lay out a roof truss not to skimp material too much, but make sure the truss will carry its load safely under all conditions.

CHAPTER XXXI.

Roofs for Studios.

Fig. 89 gives a side elevation of one of the completed trusses, showing its main details. B, Fig. 89, is a lower chord or tie beam running across the house from wall to wall, being supported at M and N by heavy 12 x 12 inch columns of wood. C is an upper chord in compression of the same size as B, which is in tension. D is the sloping rafter on the north side of very steep

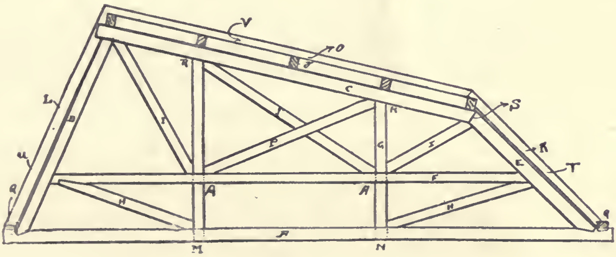

Fig. 89.

pitch to receive the full effect of the northern light which is essential in order to obtain the very best working light underneath. As every carpenter knows the value of the northern light in filing saws and so forth, I need not go into lengthy explanation as to why this side of the roof is so high and the pitch so steep. E is the principal rafter on the south side of the roof set at an angle of about 45° in order to gain the full benefit of the southern light in bringing out artistic effects in paintings, statuary, etc., and here I would state that photograph galleries, usually on the top stories of buildings, have the roof constructed of this form so as to obtain the best lights and shadows on the man or woman beneath when having his or her picture taken, for the true photographer, if he be an artist, always strives for the most artistic effects of light and shade, especially on the features.

From this short explanation any one can see why roofs for lighting are thus constructed.

Referring again to Fig. 89 it will be noticed that a special form of bracing is introduced, to properly support the great weight of glass in the roof, and to stiffen it sufficiently to resist wind pressure. H, H; I, I, and P, P, being mortised and tenoned tightly in at the angles to carry the strain all down to the posts and columns. The joints marked A were halved together and those at M, N and R, R were dowelled as was the abutting joint S. Q and Q are the two longitudinal wall plates, which carry the rafters T and U; the deck or top rafter V, resting on and nailed to the longitudinal purlins J. On account of the great height of this roof, the North principal rafters D being 20 feet long, it will be seen that there was ample room for studios in its interior, the trusses being spaced 15 feet apart. The span over all, from outside to outside of walls, measure 50 feet; lower chord, 12 x 14: principal rafters, 12 x 12; braces, 10 x 12; plates, 6 x 8; purlins, 8 x 14, so that it will be seen that it is an unusual roof. The rafters were arranged for receiving the glass with a groove to carry off all condensed water or possible leakage from rain.

CHAPTER XXXII.

How to Build a Circular Framed Tower with a Molded Roof.

Circular towers in framed construction may be divided into two classes—namely, those which have their foundations on a line connected with the main foundation of the house, and second, those which are carried up from the second floor, resting on, or being supported by, the floor beams of the second story. The latter class will be considered, as it embodies more important construction, although some of the matters which will be treated are applicable to all circular towers. The first thing for the practical carpenter or builder to consider is how to so construct the floor as to support the tower in a proper manner; that is, so that it will sustain with perfect safety the weight to be placed upon it.

Referring to the accompanying illustrations, suppose Fig. 90 to represent the general appearance of a tower built on an angle of a house. It is placed at the left hand of the front of the building and is designed to form an alcove closet, or an extension to the corner room. Its plan, as may be seen from an inspection of Fig. 92 of the engravings, is a three-quarter circle, the apex of the angle at the corner being the center from which the circular plan is struck. The radius of the plate outside is 3 feet 9 inches, thus making the tower 7 feet 6 inches in diameter. It is intended that the tower floor shall be

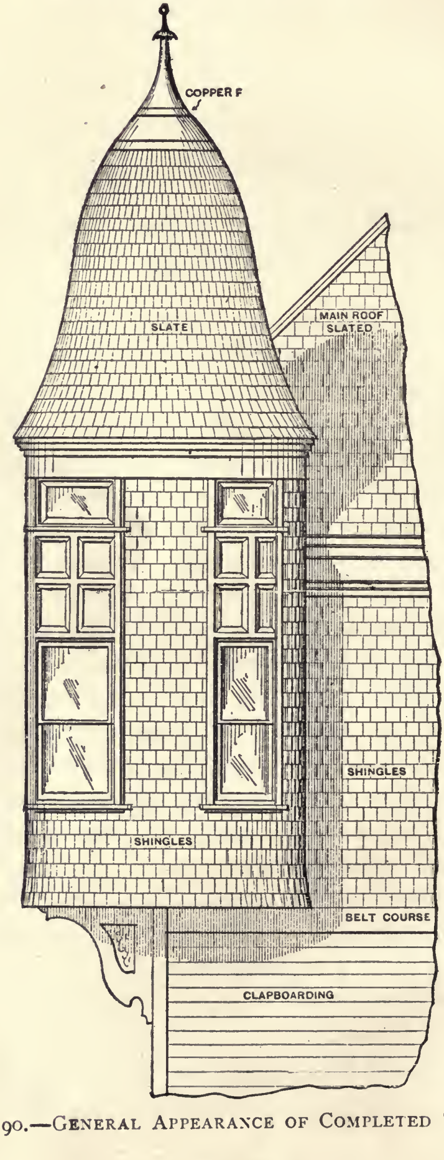

Fig. 90.—General Appearance of Completed Tower.

level with a room in the second story, and the beams or joists must be framed in such a manner that the flooring can be laid in the circle of the tower, while at the same time being so secured as to support the weight of it. The form of construction indicated in Fig. 92 is well adapted for the purpose, and an inspection will show that it consists of a double header made of 2 x 10 inch timbers placed diagonally across the corner at a sufficient distance back from it to give ample leverage to counterbalance the weight suspended outside the plate.

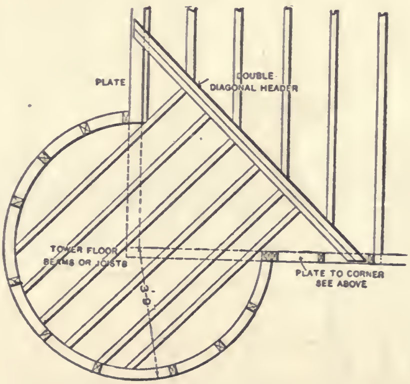

Fig. 92.

The tower beams are framed square into this header on the outside and the floor beams are framed into it on the inside. By this construction a cantilever is formed, for the header in carrying the main beams forms a counterpoise for the superadded weight which is borne by the unsupported beams which project outside. It will be readily seen that this is a good construction, and much better than introducing many short timbers after the manner indicated in Fig. 93 of the engravings. In the latter case the leverage outside being much greater than that inside, the plate being the fulcrum, there is a strong probability of its tearing away from the main

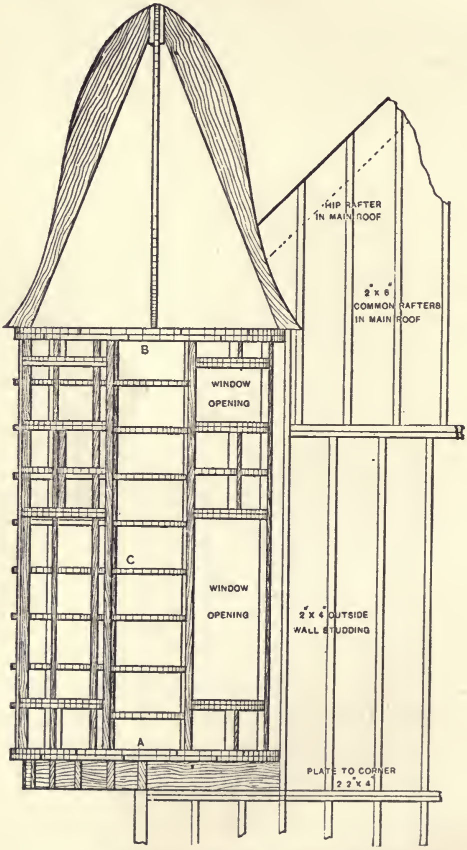

Fig. 91.—ELEVATION OF TOWER FRAMING.

framing. For the same reason it is regarded as a serious mistake to attempt to radiate the timbers as indicated by the dotted lines in Fig. 93. The position of the timbers are better shown in the elevation of the framing, Fig. 91, and we have no doubt that practical carpenters will fully appreciate what has been pointed out.

When the beams are inserted and the main framing has been nailed, a bottom circular plate, or template, marked A, in Fig. 91, is made from two thicknesses of 1-inch stuff, and nailed on exactly the size required. The position of the window studs is also marked on it,

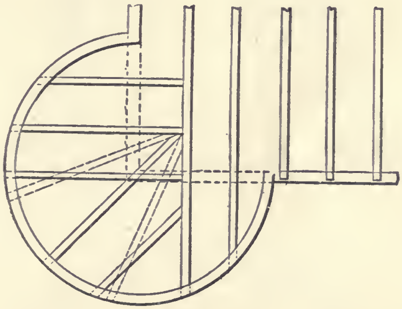

Fig. 93.

as represented in Fig. 92. The upper plate, or which is really the wall plate proper, and indicated by B in Fig. 91, must also be made, and this will rest on the top ends of the studding and support the rafters. This plate will be a complete circle measuring 7 feet 6 inches in diameter and struck with a 3 foot 9 inch radius rod and laid out upon the floor, as indicated in the roof framing plan, Fig. 94. The pieces necessary to form the upper and lower plates may be sawn out of rough 1-inch pine boards from one pattern, which may be any one of those drawn in the plan, and a number of which go to make

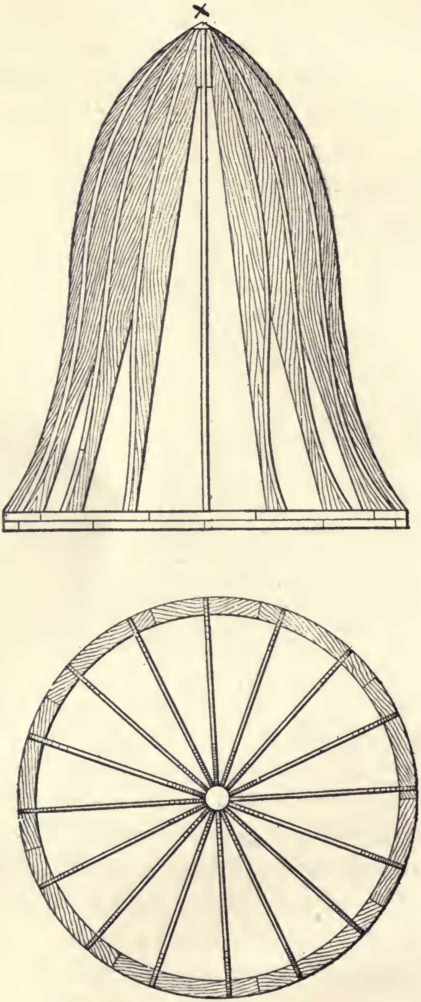

Fig. 94.—View of Rafters.

up the whole plate. The studding are cut 11 feet 8 inches, which being added to 4 inches, the thickness of the plates, makes the entire height 12 feet. The window headers, both at the top and bottom, are likewise *circular* and are framed in after the manner represented in Fig. 91, to form the openings and cripple or short studding cut in under them in the center. All studding must be set perfectly plumb and all plates and headers perfectly level. In order to insure this it is well to be certain that the bottom plate is level by placing a parallel straight edge with a spirit level on top of it, across the plate at different points. Then, if the studding be cut of equal length the upper plate must, in consequence, be placed in a level position. A number of horizontal sweeps, 2 inches thick and 4 inches wide, as indicated at C in Fig. 91, require to be cut out to form ribbing or pieces nailed in 16 inches apart, to which the vertical boarding outside and the lath and plaster inside are fastened. It will be seen that if this construction is followed the whole cylindrical wall can be very strongly and economically built up. To save time and labor and also to expedite matters, the sweeps may be sawed out at the mill with a band saw, although it can be done in pine on the job with the compass saw.

With regard to the molded roof, it may be said that having a molded outline it will necessarily require molded rafters sawn to the curvature called for in the elevation. As a general thing, architects furnish a full size working detail for roofs of this kind, but it often happens that it is not forthcoming and the carpenter or builder is obliged to strike out a pattern rafter himself. To do this quickly and as accurately as possible, it is well to lay out the whole roof on a floor, something after the following manner: Referring to Fig. 95, draw any base line 7 feet 6 inches in length, as A B, and divide exactly in the center, or at 3 feet 9 inches, as C. From C square up the line to 9 feet high, as C D, and divide this line into 13 equal divisions, as 1, 2, 3, 4, 5, 6, &c. Through these points draw lines parallel to A B, or square C D any length on each side of C D. Now, from the point D draw the curve of the rafter, as indicated by the letters E, F, G, H, I, J, K, L, M, N, O and P, as near to the outline as possible. A very good method of obtaining these curves is to divide the architect's ¼-inch scale drawing by horizontal division lines similar to those in Fig. 95 and to scale off the lengths from the axis or vertical line C D. By setting off these measurements on a full size lay out, points will be obtained through which the flexure of the curves may be very accurately determined.

The 16 rafters may all be drawn from the one pattern, as they are all alike and should be framed to fit against a 3 inch wood boss as indicated by X in Fig. 94. In this engraving the rafters are shown in position in elevation and also in plan, as well as the way they radiate or are spaced around the circle 16 inches apart on the plate. As it is always best to board such roofs as this vertically, ribbing or horizontal sweeps will have to be cut in between the rafters, and as there should be as many of these as possible for the purpose of giving a strong framework to hold the covering boards, it is advisable to cut in one at each of the divisions marked on the elevation shown in Fig. 95. The outline plan of this figure represents the top lines of these sweeps,

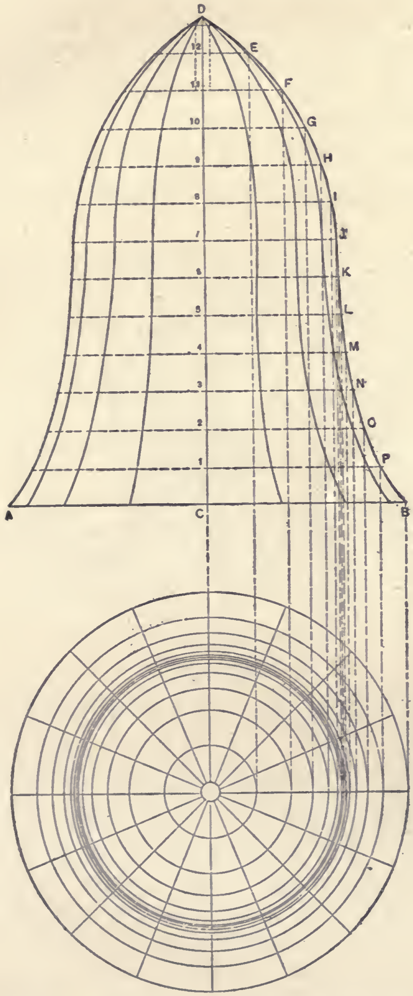

Fig. 95.—Outline and Elevation of Rafters and Ribbing Sweeps.

which are well nailed in between the rafters. Fig. 96 shows the exact size of the headers and their positions when nailed in. They are struck from different radii, which shorten as they go upward. It will be noticed that each set of sweeps is consecutively numbered with the lines C, 1, 2, 3, etc., from C to D of Fig. 95. There

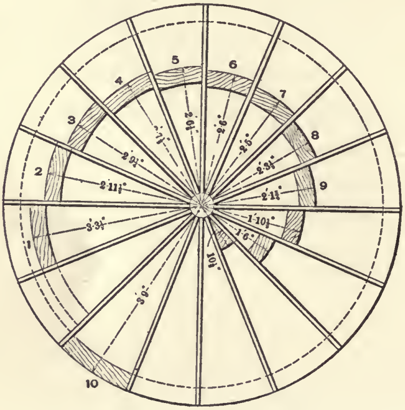

Fig. 96.

will be 13 sweeps in each course and, therefore, 15 different patterns. They may be conveniently numbered and marked in the following manner: For No. 2, for example, a pattern can be cut and marked "Pattern for 15 sweeps, No. 2." There will, therefore, be 180 altogether to be cut out, and these should be cut a trifle longer than the exact size, in order to allow for fitting.

CHAPTER XXXIII.

Details and Suggestions.

All the timber used in roof trusses, should have been felled at least two years and should have been at least six months out of water. Modern builders, but too often employ timber soaked with water, and the result after a few months is considerable shrinkage and consequent splitting from abutting joints. This very often happens with struts and principal rafters, the first at the head and the second at the feet. A good preventitive against this evil may be made, by leaving the abutting joints open at the internal angle nearest the post.

All spikes used in building construction should be flat-edged and not twisted as some are, and they should be driven with the edge across the fibre of the wood and not longitudinally with the timber which would tend to split it.

With regard to bolts, when they are round, the hole made to receive them should be exactly of the same diameter as that of the bolt, and it should be driven exactly parallel to the sides of the wood that are to be parallel to the bolt. For square bolts the bolt-hole should be somewhat less than the diagonal of the bolt.

Bolts and nuts should be well greased or dipped in oil before they are used. Bolts of great length should be of sufficient diameter to resist torsion, and they should never be placed too near the end of a timber.

Care should be taken that screw bolts and screws be never hammered, as the fibres of the wood are thereby torn. It is a great error to fancy that the elasticity of the wood will prevent this laceration.

Whenever it is feared that a nut may slacken by a retrograde motion, a check nut may be added, which will effectually prevent any loosening.

Iron straps and stirrups should always, before use, be heated to a blue heat and then struck over with raw linseed oil as a preventitive of rust. Our modern rolled and stamped straps and stirrup irons, have obviated the use of the foregoing, but the writer is glad to see that some of the older and more experienced architects insist on its being done even on the rolled straps.

A strap 1 inch wide may be 3-16 thick, 1½ inch wide may be 5-16 thick and 2 inches wide, ⅜ thick.

Straps should be secured by lag bolts, and if the timber be not too thick, the bolts should pass through it and have good large washers. Cast iron plates and shoes are very useful to receive and to equalize the thrust from the ends of butting timbers, the first particularly where they are employed as a connecting surface between the butting ends of timbers, which from shrinkage, defect of workmanship, or otherwise may come to bear upon opposite angles, instead of the whole area of their intended connecting surfaces.

It is a very dangerous practice to hammer rolled or wrought iron straps when cold, they may get an invisible fracture.

The duties of king-posts and queen-posts are now efficiently performed by wrought-iron suspension rods and they may be of from 1 inch to 2 inches in diameter. They will pass through timbers and be secured by nuts, outwardly of three times the diameter of the bolt, when in connection with struts they may pass through the cast-iron shoe receiving the strut. We may by these means suspend the tie beam from any number of points and construct a truss of great span with little weight.

It must be remembered that it is always wise to give careful consideration to bearing joints so as to ensure the stability of the structure. The methods of joining timbers are various and they should be always constructed according to the position and strain on the connected timbers at the joints; tenon and mortise, joggle, notching, butting joints, scarfing and building, or modifications of these are the principal combinations of timbers in trusses.

In tenon and mortise, the tenon is cut on the end of one timber and the mortise is cut in the face of another to receive the tenon. In the square tenon and mortise, the thickness of a tenon is made one-third of that of the timber in which it is cut; the shoulders should be in exactly one plane and perfectly perpendicular to the axis of the timber on which the tenon is cut; by these means after shrinkage there will be obtained an equal bearing which is most desirable in case of weight on the shoulders one of which would otherwise have a tendency to split from the main timber; the size or sectional area of the mortise must be quite parallel to the axis of the timber in which it is cut; when acting by suspension but little depth is required if secured by a strap. An oak pin or bolt should be driven through mortise and tenon, the whole being bored after the joint is adjusted and this hole must be quite square with the timbers. The diameter of a pin should be one-third of the depth of the tenon from the shoulders. It is not wise to depend on pins for the strength of joints as this should result from the combinations of one timber with another and it is only for the setting up that their assistance should be required.

The tenon and mortise mentioned above is applied to joints that are at right angles or square; but the

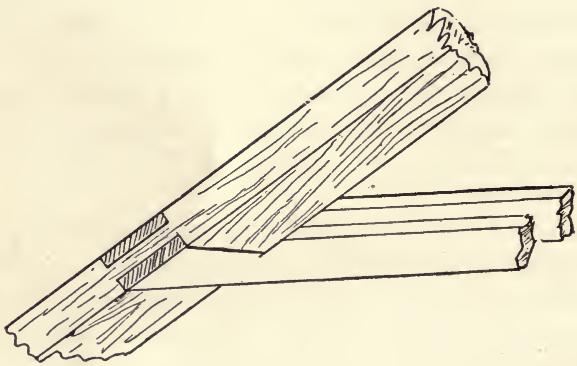

Fig. 97.

oblique or beveled joint at the feet of principal rafters demands fully as much if not more care and treatment than that described.

Let me draw attention to the fact that much more care than is usually evinced might be taken by carpenters when nailing parts of framing together, especially at the abutting ends of studding, on the top and bottom cuts of rafters and such like. As a rule I find that many of the pieces are split by careless or insufficient nailing which is done so as to split or splinter all of the stuff and lessen its holding capacity. This could be easily avoided by entering each nail more carefully. Another thing is to be sure to straighten all studding, beams and roofing timbers through from end to end so they will be set rigid and upright, in order to gain their utmost strength. If any timbers be warped they should be straightened up or bridged in some way so they will not twist more. The foregoing I would especially apply to hemlock and spruce, as many pieces are warped and need a little care.

Fig. 97 represents a joint in a truss roof on a school house at Eighty-fifth street and Madison avenue, in the City of New York, introduced for the purpose of preventing the principal rafters from buckling.

SHRINKAGE OF TIMBER BY SEASONING.

Southern yellow pine............	from	$18\frac{3}{4}''$	to	$18\frac{1}{4}''$
Spruce.......................	"	$8\frac{1}{2}''$	"	$8\frac{3}{8}''$
American white pine............	"	$12''$	"	$11\frac{7}{8}''$
Cedar.......................	"	$14''$	"	$13\frac{1}{4}''$
Elm.........................	"	$11''$	"	$10\frac{3}{4}''$
Oak.........................	"	$12''$	"	$11\frac{3}{8}''$

VERTICAL PRESSURE ON ROOFS.

Roofs covered with corrugated iron—without boards, the pressure to the square foot is....	8 lbs.
Same, and plastered below rafters............	18 "
Covered with slate laid on 1 x 2 inch lath......	13 "
Same, and plastered below rafters............	23 "
Covered with slate on 1¼ or ⅞-inch boards...	16 "
Same, plastered below rafters................	26 "
Shingles on 1 x 2 inch lath..................	10 "
Same, plastered below rafters................	20 "
Shingles on boards........................	13 "

This table for spans not exceeding 75 feet. From 75 to 150 feet, add 4 pounds to each number.

AVERAGE WIND PRESSURE.

Pitch in degrees.	Rise of roof.	Pressure in lbs.
5°	1″	5.2
10°	$2\frac{1}{8}$″	9.6
15°	$3\frac{1}{5}$″	14.0
20°	$4\frac{3}{8}$″	18.3
25°	$5\frac{1}{2}$″	22.5
30°	$6\frac{9}{10}$″	26.5
35°	$8\frac{2}{5}$″	30.1
40°	10″	33.4
45°	12″	36.1
50°	$14\frac{3}{10}$″	38.1
55°	$17\frac{1}{8}$″	39.6
60°	$20\frac{3}{4}$″	40.0

The above table is for the pitches mostly used by architects.

In conclusion I would recommend mechanics to be more particular and spend more time on the process of measuring, and note down any peculiarities that may exist in the construction and make sketches and remarks about same especially when measuring up for new work.

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The length of common, hip valley and octagon hip rafters.

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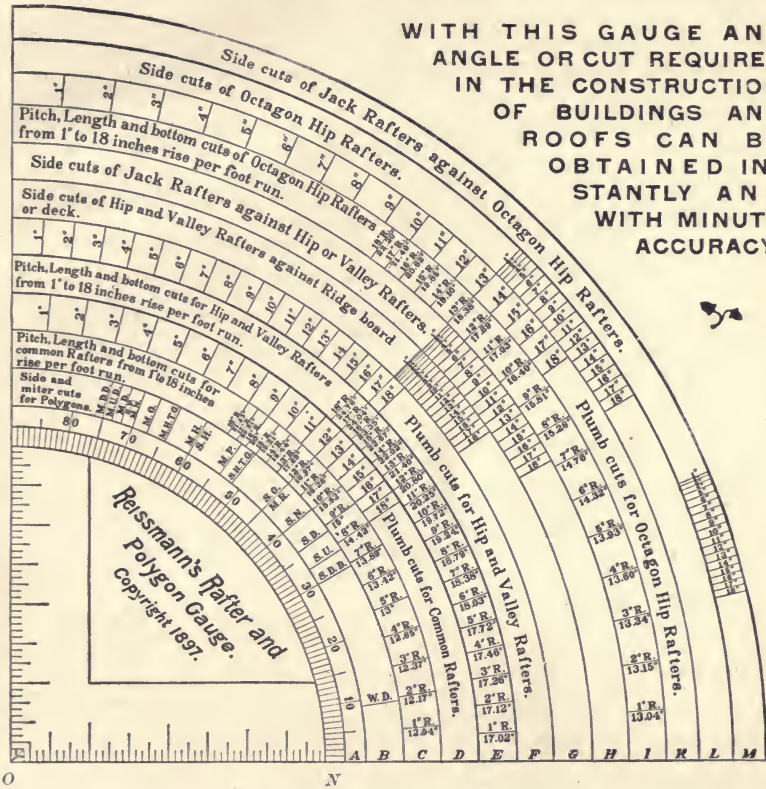

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To obtain any desired angle in the construction of buildings and roofs, apply the tongue of an ordinary carpenter's sliding **T** bevel against the edge of gauge marked **N**; then move the blade of level so that its outer edge will coincide with the arrow point on gauge marked **O** and the line from which the angle is to be taken.

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