Dr. Grant's System of Railing Spiral Stairs

Dr. C. C. Grant
Box 422
Red Deer, Alberta

DR. CHARLES CYRUS GRANT'S SOLUTION OF FERMAT'S PROBLEM

This solution was arrived at in the City of Red Deer, Alberta, on the first day of June, in the year nineteen hundred and fifteen, by Dr. Charles Cyrus Grant.

The problem may be stated as follows: x^p cannot equal $m^p + a^p$ when x, m and a are rational and p an integer greater than 2.

A succession of statements will show how x^p, m^p and a^p can be secured.

$$
\begin{array}{lcl}
x \text{ may or may not} & = & m + a, \\
x^2 \text{ `` `` `` ``} & = & m^2 + a^2, \\
x^3 \text{ `` `` `` ``} & = & m^3 + a^3, \\
\cdot \quad \cdot \quad \cdot & \cdot & \cdot \quad \cdot \quad \cdot \\
x^{p-1} \text{ `` `` `` ``} & = & m^{p-1} + a^{p-1}, \\
x^p \text{ `` `` `` ``} & = & m^p + a^p,
\end{array}
$$

where x, m and a are the ultimate and pth roots of x^p, m^p and a^p respectively, that is x, m and a cannot be the same powers of rational numbers, though any one or more of them may be a power of a number.

Any statement of the series except the first may be secured by multiplying the terms of the preceding statement by the roots x, m and a respectively.

Equality of the sides of a statement depends on the relations of the terms multiplied together. The problem then is to discover where those relations exist, provided they do exist.

The relations of the terms of a statement will not be altered if we multiply or divide each and every term by the same number, nor will they be altered if we multiplied or divided the roots x, m and a by the same number. For instance, $-xt$, mt, and at, become $x^r t^r$, $m^r t^r$ and $a^r t^r$ where manifestly $x^r t^r = m^r t^r + a^r t^r$ if $x^r = m^r + a^r$. This enables us to make x, m and a whole numbers if one or more of them happened to be fractions, but would not enable us to make x, m, and a whole numbers if one happened to be irrational. This excludes irrational numbers.

If equality exists between the sides of any statement in our series other than the first statement, then x must be less than $m + a$, for if not equality could not be found in any other statement, since the multiplier x of one side of the statement would be greater than the multipliers of the other side of the statement. Hence multiplication would create or increase inequality. Similarly x is greater than m or a.

m^r cannot equal a^r in any case of equality where r is greater than 1 since x would in that case equal $m\sqrt[r]{2}$ and could not be rational. Let m be greater than a.

The relations of the terms of a statement will be altered if we multiply or divide each term of the statement by a different number, as for instance—when we multiply the terms of one statement by the roots x,

m and a respectively, to secure a succeeding statement, that is equality is only possible in one statement of a series.

Let $m + n = x$. Then in any case of equality say $(m + n)^r = m^r + a^r$, a is manifestly greater than n if r be greater than 1. Divide the roots x, m and a, respectively by n and call the quotients x', m' and a' respectively. Then $x' - m' = 1$, a' is greater than 1, m' is still greater than 1. Hence x' is greater than 2. This shows that the relations of x', m' and a' are limited, which could not be if essential relations did not exist between x', m' and a' that is between x, m, and a.

As shown above these essential relations cannot be found in any statement other than the first, that is the statement x may or may not equal $n + a$. Hence the terms of no other statement can be used as multipliers, that is equality can only be secured by multiplying x, m and a by the roots x, m and a respectively.

That is equality is impossible when p is greater than 2.

Q. E. D.

Dr. GRANT'S SYSTEM

OF

RAILING SPIRAL STAIRS

THIS HITHERTO
UNSOLVED PROBLEM SOLVED

THE SOLUTION
IS EXCEEDINGLY SIMPLE

A FEW REMARKS ON THE TANGENT SYSTEM ARE ADDED

PREFACE

This book is written in the hope that, by its means, Spiral Stairs may become general.

A circle, or an ellipse, will be considered the perimeter, or enclosing line, in each case.

When the plane of the circle, or ellipse, is meant, it is so stated.

Any stair, or that part of it at least, which climbs a column, circular or elliptic, will be termed spiral, whether it climbs regularly or irregularly.

Many mechanics can build a spiral stair, or could easily learn. Few can put a rail of any kind on a spiral stair. Up to the present no system has been evolved to do the work, and years of constant practice were necessary to enable the mechanic to do what was done.

A system for rails of an elliptic nature was evolved by Nicholson, and later, was simplified by Riddell, which endeavored to furnish a face mould, a joint on each end of a crooked chunk of wood, with a line on the face of each joint.

Riddell, in his second edition, admits that the system failed to do even that much; and calls in "a skillful hand" to correct the "deformities" produced by it.

All modern works on railing are founded on Riddell, and merely attempt to simplify his methods.

The result is that spiral stairs have not become general.

In their place we have that abomination known as posts, which take away a hand-hold just where it is needed, that is at turns; which narrow a stair just where room is needed, that is at turns; and which for unsightliness could not well be excelled.

The advantage claimed for the post is the safety of the platform sometimes used with it. The latter is an argument for platforms, not for posts, and spiral rails can be used on these stairs as easily as elsewhere. A continuous hand-hold is thus furnished at the turns, and more room secured at the same time.

The author considers that a matter so simple as the railing of spiral stairs should not be permitted to stand in the way of their general use, especially when their proper railing is a task not nearly so difficult as that of hanging doors.

This system is so nearly automatic, that good men should learn to put a rail on any spiral stair, in an hour, by merely looking over the figures and reading the cautions. This, however, is not advised. The book is brief. Read. Learn the principles and cautions.

No man can be an expert in anything without practice; so make miniatures out of some soft wood. By the time two or three are made, the ordinary workman will be ready for anything.

A few remarks on the tangent system are added.

C. C. Grant, M. D.,
Red Deer, Alta, Canada.

STAIRS WITH CIRCULAR COLUMNS

(For Explanatory Illustrations See Back of Book)

Essentials.

A ground plan, Fig. 2, containing: the centres of circles; side and centre lines of rail, both on the straight and circular parts; position of risers; and position of newels and landings, if any.

All straight lines must be extended.

Radial lines must be drawn through the centre of the circle and the points where the risers cut the centre line of rail, also where the straight and circular parts meet, Fig. 2.

These radial lines must be extended.

This plan should be on a good level floor.

An elevation plan, from which can be secured the height of the rise, the height of the rail generally, and also at newels and landings.

The elevation plan will seldom be needed if the mechanic has built the stair.

A pattern of a cross section of the rail on the straight.

Fundamental Principles.

Consider a large screw, such as that of a jack-screw, stump machine, or large iron lathe. Suppose it in a vertical position.

Observe that, the outer surface of the thread is at a uniform distance from the axis of the screw.

That, a radius kept at right angles to the axis, and at the same time swung around and moved up and down will, when in contact with the thread above or below, touch the upper or lower surface, as the case may be, all the way across.

That, if two points be taken on that radius, at distances from the axis equal to the distances of the inner and outer surfaces of the thread, these two points can be made to follow the four corners of the thread exactly; and, if the radius be raised or lowered, the points will always be vertically over or under the corners of the thread.

That, the corners of the thread, which are curves, climb upward at a uniform rate, Fig. 1.

That, if the body of the screw be supposed removed, and the thread left, that thread is a body of a spiral nature, whose inner and outer surfaces are determined by the four corners mentioned above.

That, the corners are curves of more than one dimension, if a circle, C, or an ellipse, E, Fig. 3, be classed as curves of one dimension, that is, no plane will fit the corner of the thread; whereas a circle or an ellipse will lie on a plane.

That, if a piece of tin or veneer be started correctly on the inner or outer surface, it will follow that surface.

Consider an ellipse, Fig. 3, E, made by a plane section of a cylinder in a vertical position.

Observe that, it climbs the cylinder at a constantly varying rate and never ceases to change form.

That, it becomes level at Fig. 3, L, runs down the other side, becoming once more level, and then goes up where it went previously.

That a piece of tin or veneer will not follow it.

Consider a string of a regular spiral stair and its construction, especially one made with a straight piece of veneer.

Observe that, in every respect it resembles a spiral, and in no respect does it resemble an ellipse.

That, the rate of climbing of an ellipse is governed by a straight line called the major axis, and that the ellipse is located along level lines at right angles to that axis.

That, the rates of climbing of a straight veneer stair string and of a spiral are governed by the circumferences of the cylinders they climb, and that no straight line can possibly have any control over either.

One conclusion only is possible; viz., that a rail, to be true and fit a spiral stair, must be of a spiral nature, and must not be of an elliptic nature.

It seems that the stair maker solved the problem of climbing uniformly when he made the string, whereas the rail maker, if he ever solved it, has forgotten the solution.

Definitions.

Fig. 2. C is a circle.

AB is a diameter.

AD is a radius.

BE is a tangent.

The angle ABE is always a right angle with circular columns.

A tangent, as BE, touches a circle in one point only, and does not cut it.

A wreath, Fig. 4, is that part of a rail which stands over a curved part of a stair, no matter where.

Purely horizontal wreaths will not be dealt with. No difficulty can arise with them.

An easing, Figs. 5 and 13, is used where differing pitches meet, where straight and circular parts meet, and also at newels and landings.

Purely vertical easings will not be touched upon. They are always used where differing straight pitches meet, and no difficulty can arise from them.

Pitch is the angle made by a straight part of a rail with a level line vertically under the rail.

The straight rail in last sentence may be a circular part unfolded.

Tools.

Good tools should be used, such as Figs. 6, 7, 8, 9, 10, 11, 12.

Fig. 6 enables the head, Fig. 8, which carries the pencil holder, to partly pass the shaft, and thus allows the pencil to approach the shaft.

Fig. 11 is not patented by the author.

Many kinds of tools could be devised to do the same work, as, for instance, those which appear in the photographs.

Steel points, similar to those seen in the photographs, are necessary to support the plank, they are preferable to Fig. 11 for that purpose.

Clamps, Fig. 11, or something of that nature, are needed to hold the plank when a band saw is used to cut out the wreath; inclined planes could be made to do the same work.

Fig. 7 explains itself.

Fig. 8 is used on the end of tram arm of Fig. 7, and carries the pencil holder and pencil.

Fig. 9 is represented in use in Fig. 13. It is used in tram head, Fig. 12. With this tool points can be put on one side of the wreath corresponding to points or lines on the other side.

Fig. 10 is used in tram head, Fig. 12, for the purpose of marking the joints. The wreath would never be moulded at time of marking, as shown in cut, see Fig. 18.

A drum, Figs. 14, 15, etc., is essential. It prevents mistakes and corrects them if made. It is the size of the inside circle of Fig. 2. The shank or flat part of the drum must extend far enough to reach the straight rail past the easing.

The same drum heads will do for bending the string, and for rails by changing the slats.

The slats should be of some soft wood, and screwed to the heads. They should be hollowed on the inside to fit the heads. Holes must be bored accurately through the heads for the shaft. A half inch gas pipe answers for a shaft when good tools are not available. It must be stayed vertically up from the centre of the circle on the ground plan, as D, Fig. 2, in such a way that its upper end may be easily freed.

A piece of tin or veneer as broad as the rail is deep.

A steel rod that will bend in all directions, and regain its form. An umbrella rib will do, but not well.

In home made tools, parallel holes for pencil holder and shaft can be secured as follows: Take two boards, square across one at the proper distances, run a saw cut along the squared lines from one-sixteenth to one-eighth of an inch deep. Screw the boards together. A bitt will follow the saw cuts.

Railing.

Imagine the screw, dealt with above, to be the size of the cylinder of the stair, Fig. 2.

It is evident that the thread, if it climbs the cylinder at the proper grades, is a rail for that stair, correct in every way, and that everything said on the screw applies, except possibly uniformity in climbing.

The thread can move up and down the cylinder regularly or irregularly, but never away from it.

The problem of railing is thus reduced to constructing a thread with the proper grades.

Suppose the cylinder removed and its axis left in position, Fig. 4.

Suppose a plank, Fig. 4, is so set that it contains within its boundaries the desired wreath.

It is evident that, if we use a tram, Figs. 4 and 7, which will act as the radius did, that then we have a means of putting four lines on the plank, two above and two below, which determine the inner and outer surfaces of the wreath exactly.

These lines can be joined, two and two, across the ends of the wreath block with the tram if desired, by using pencil in horizontal hole of Fig. 8.

The above is true for any kind of a rail climbing a circular column.

The problem of getting the inner and outer surfaces of the wreath-block is thus reduced to setting the plank in the proper position.

Always make the wreath with a shank if possible. Thicker timber is needed usually, but the result is better, one joint being got rid of. Joints always weaken the rail, hence, the fewer the better.

Before going further, it may be well to state that with shallow rails the balusters may be of the same length, not counting easings, but when the rail is deep, and the pitches vary, the height of the top of a rail would vary greatly by so doing.

The reason is obvious: the steeper the pitch, the longer the plumb line which crosses the rail. Hence the distance from the bottom of the baluster to the top of the rail, would be greater on the steep pitches than on the flatter ones. Therefore, in such cases at least, if not in all, it is better to keep the top of the rail at a uniform height. An exception to this last occurs with stairs, whose risers do not radiate from the centre. That is, they do not follow radial lines through the face of the risers, where they cut the centre line of rail. It is well in such cases to lower the rail when the riser is further around the stair than the radial line is at the wall string, and vice versa. The same thing will be referred to in elliptic stairs.

If it be decided to raise or lower the rail, as suggested above, it is only necessary to change the radials described on page 5.

With the ground plan centre, and radius equal to that of centre line of rail, plus eighteen inches, describe a circle, Fig. 2B.

This circle will be on what may be called the walking line of the stair.

Draw the radials through the centre and the points of intersection of this circle with the faces of the risers, Fig. 2B.

No other change is necessary.

Set the drum on the ground plan.

The ground plan used in preparing for photographs and drawings was irregular, to show easings.

Plumb up on the drum from the radial lines for the circular parts, and from the risers on the flat or shank parts of the drum, Fig. 5.

With compasses, find if the radial lines cut the circle on the ground plan at uniform distances, or if any adjacent spaces are the same. and mark, if any. When the distances are uniform, the stair climbs uniformly, and if two or more adjacent spaces are the same the stair climbs uniformly at that part. If all the spaces vary the stair does not climb uniformly anywhere.

Place a cross on the vertical line plumbed up from the lowest riser, Fig. 5. This riser must be past the easing.

Place a cross on each of the vertical lines raising the cross on each in succession the height of one riser. This height is got on the elevation plan. If height of rail on landings differ from that on the stair, allowance must be made.

Risers are always the same, or should be. The steps only should vary on the same stair. If such a thing as variation in rise does take place, get each rise on the elevation plan and put on cross lines accordingly.

Run a pitch line on the shank part of the drum through the first or lowest cross, Fig. 5. The pitch is got on the elevation plan.

Take the tin, mentioned among the tools, and, if you want the balusters uniform in length, place it on the drum so that its lower edge coincides with the pitch line just put on. If you want the top of the rail uniform in height make the top edge of the tin coincide with the pitch line. The above applies whenever and wherever the tin is used.

Clamp the tin in position on the shank part, and wind it around the circular part a few inches.

Mark top and bottom, always continuing the lines a few inches on the circular part, Fig. 5.

If the stair climbs uniformly, apply the tin to the crosses on the circular part, exactly as it was applied to the pitch line on the shank part.

Mark both sides, taking care to go far enough to cross the lines previously put on, if the lines do not run into one another uniformly, and so on.

If the stair be irregular in parts, apply the tin as before to the regular parts, and do as before, always continuing the lines far enough to cut each other. If the stair is altogether irregular, use the splan or steel rod, which should be long enough to go around the cylinder in such cases, and make it assume the position which best suits the eye and the stair.

Where lines cut each other use the steel rod to put on easings, Fig. 5.

When the steel rod is used only one line will be secured.

Set the compasses at depth of rail, and make dots or arcs with them at right angles to a tangent to the line already on. Join the dots or arcs with the steel rod. This gives the other line.

Caution.

The tin will not give the same depth of rail on the shank as on the drum, especially if the drum be small and the rail be deep in these cases, it is best to mark the side of the tin applied to the crosses only and use compasses as for easings.

In what is called regular stairs the tin will not run off the circular parts on the shank parts correctly. There is practically always an easing, Figs. 5 and 13 do not show it in all cases, but should.

Tin applied to the inside of a wreath will not run out on the shank part, so as to correspond with the direction it will take on the outside. Keep this also in mind and save trouble later.

Always put the pitch lines on the shank parts. Do not trust the tin.

Place vertically on the drum blocks as broad as the rail, and so that they will just reach the two lines, Fig. 14. Place one at each end of the wreath, and one at the most dependent or elevated parts. Put on enough. These blocks should be very thin. Figs. 14 to 20 will fully explain the tools used in preparing for photographs. They are all home made and cost little.

Set the stands, Fig. 15, so as to be clear of the circle and tram, Figs. 15, 16 and 17.

Drop the long curved points out of the way, Fig. 15.

Set the parallel boards on the outer points, Fig. 15.

Arrange by moving the points up and down, and also by widening or narrowing the space between the boards, by means of the wood screw, Fig. 15, so that the space between the boards will just contain the blocks on the drum, when looking along the top of the bottom board, and the bottom of the top board.

It is evident, if a plank be as thick as the boards are apart, that then it will be thick enough to contain the wreath, if put in the position the boards occupy on the points.

If only one thickness of plank be available, set the parallel boards as far apart as the plank is thick, and manipulate so as to contain the blocks on the drum, if possible, if not possible, then the wreath piece must be shortened, the rail made smaller, or thicker plank secured.

The plank itself may be used instead of the parallel boards, but gives more trouble, the blocks being hidden from view by the plank.

If the plank be broad, set it at once on the outer points, after removing the drum, taking care to place it so that it will contain the wreath sideways and endways. This can be seen from the ground plan at a glance, or by plumbing or squaring up from the ground plan.

If the plank be narrow, set the three long curved points near the drum, and so that they just appear when looking over the top of the bottom board. They would be in the position shown, Fig. 17. They are useful in any case because they furnish a foundation to lay the wreath block on later, Fig. 17.

If these points are not set, it is better in all cases to run a straight edge along the top of the bottom parallel board, bringing it in contact with the drum and marking where it touches. This gives the exact position for the wreath block later, as the points do, Fig. 17.

In all cases put on all tangent and shank lines, Figs. 3 and 16. This is done by placing a straight edge on the extended tangent lines on the floor, and bringing it in contact with the curves put on by the tram, Figs. 3, 4 and 16.

At newels and landings, where the rail comes level, the drum is marked in a slightly different way.

The same plumb lines go on, also one at face of newel or landing as the case may be.

Cross lines go on as before, also one on the newel or landing vertical line. Shank lines go on as before.

The steel rod is clamped level at the newel or landing cross, and wound around the drum, running into the shank line with an easing. Little attention is paid to the intervening crosses except in a general way, Fig. 5.

If desired, the rod can be run into both the shank and the landing lines with an easing.

The most graceful curve possible can be secured in this way. Always make a gradual curve, and keep as far as possible from the dumpy, irregular kinked curve of an ellipse at the end of its major axis, the only part of an ellipse that is level.

Any wreath, with or without a shank, that can possibly be conceived of, can be traced on the drum as above, and a plank can be set for it as above.

One is just as simple as another, except that taste is needed in the easings. It is merely a question of suiting the eye.

The plank should be smooth to enable the pencil to move freely.

If interruptions appear on the lower surface of the plank, owing to using the long curved points, bridge them over with the steel rod.

If good clamps are available, such as Fig. 11, or some form of inclined plane, to hold the plank in position, the wreath can be sawn out with a band saw.

Very little work will be left on the inner and outer surfaces, if the saw is used.

Work the inner and outer surfaces with planes, a large round one on the inside.

CAUTION.—Work in a direction that would be plumb if the wreath were in position.

Work plumb, or you will spoil the wreath.

If there is a joint in the wreath, locate it at right angles to the lines on the drum, and extend it both ways on the drum.

If good tools are available, use joint square, Fig. 10, resting it on the plank of Fig. 18.

Place lower wreath block in position and mark it. Remove it and put in the piece above, without moving the joint square, and so on.

Some slats must be removed to use the square.

If a joint square is not available, the plank alone, Fig. 18, will answer.

The plank is set in both cases by the lines at right angles to the wreath lines on the drum, and if thick, and its edge square, it sets itself the other way against the wreath block by touching on a plumb line.

A rule or straight edge rests on the plank or joint square, and is brought in contact with the wreath block for marking.

In this system joints can be anywhere in any direction.

They should always be square with the rail to prevent a tendency to slip when bolted together.

Fig. 19. The joint was made at random. It is not in the centre. It is not square. It demonstrates the indifference of the system as to joints.

Cut the ends a trifle full.

Clamp the pieces on the drum. One will be a little out of place owing to length.

Saw them together in every case. The one out of place will go into its place, the extra length being removed by the sawing.

Remove the wreath blocks.

Remove alternate slats, leaving in every case the slats on the shank part of the drum at the junction of straight and circular parts.

Square across the edges of the remaining slats for every line on the outside of the slats. Do not omit the casing lines.

Replace the blocks on the drum.

Put dots on the inside of the blocks corresponding to the lines just squared across the slats.

Mark across the joints, if any, so that the two pieces may be replaced in exact position.

Remove the blocks, and connect the dots exactly as the lines were put on the drum.

Remove more slats, leaving only enough to hold the wreath blocks.

Replace blocks on drum, and with level tram head, Figs. 9, 13 and 20, put dots on the outside of the blocks corresponding to lines on the inside.

Connect dots on the outside as before with tin and steel rod.

Owing to the fact, as will appear later, that the outside curves climb at a lesser pitch, than the inside curves, the above method produces a rail deeper at right angles to the curves on the outside, than on the inside. This is especially noticeable with small cylinders and broad rails. In such cases at least, it would be better after placing the lines on the inside surface of the wreath, with a pair of compasses set at half the depth of the rail, to make small arcs from either top or bottom line, and connect the curves with a steel rod. This gives centre line of rail on the inside. Transfer this line to the outside with level tram and steel rod. This gives centre line of rail on the outside. With compasses set as before, make arcs for top and bottom lines, on the outside. Connect as before, with steel rod. The rail will now be of equal breadth at right angles to the curves, and will mould more easily. Neither top nor bottom of rail will be level, on radial lines.

Remember not to omit shank lines. They are got on the inside exactly as the lines were got on the circular part, that is from lines squared across edges of slats.

The outside shank lines can be got as on the drum at the commencement, or by squaring.

Do not omit lines at the junction of straight and circular parts. These are got from the edge of the slat at the junction and a radial line through the junction.

The top and bottom of the wreath may be sawn out with a band saw, by rolling the wreath on the table.

It is best, however, not to cut too close, unless the workman has experience. The same thing can be done by hand, with what is called a frame, or breaking, saw.

Always keep the saw in the line of a radius, and the lines on the wreath block then guide you. The shank part is sawn squarely through.

CAUTION.—The level tram will not work beyond the junction of the straight and circular parts.

The reason for putting lines on the inside first, instead of the outside, is as follows:

The inside corners of a wreath climb as high as the outside corners. They climb a smaller cylinder. Their pitch is therefore greater. They run into the same pitch on the shank. Something in the nature of a kink is inevitable. It is more apparent on the inside, being smaller, and seen from the inside of the curve. It is of little consequence with large cylinders and narrow rails. It attains its maximum with pitches of 45 degrees, and diminishes both ways, vanishing at newels and landings, where the wreath comes level, that is, landings without easings.

Another feature: The junction of straight and circular parts is plumb.

It follows that a straight shank side is opposite a curved wreath side.

To meet these difficulties, an easing running into the shank is usually necessary.

These difficulties must be met by all systems of railing. They are inherent in what is being attempted.

CAUTION.—The only level or straight line, on the top or bottom of a wreath, runs through the axis.

Work top and bottom towards the axis.

Work to nothing but lines.

Do not try to square joint ends in a climbing wreath. They are never square. Figs. 21, 22 and 23. No pattern will fit them.

To work the top and bottom of joints, remove slats near the joints, and clamp wreath blocks in position on the drum. Then work the top and bottom at the joint as other parts are worked.

This does away with all necessity of top and bottom lines on the ends of the wreath blocks.

This system is so nearly automatic that a workman has little to think about, beyond keeping the cautions constantly in mind.

The thread is now made.

Bolt pieces together, and put on longitudinal lines to aid in moulding the wreath. These can be run on with rule and pencil, or with pencil gauge.

There is a method of setting planks and making rails of an elliptic nature. It starts where Riddell leaves off.

The moulds, joints and bevels of the tangent system are not required.

The method is not inserted.

The author does not want it said, that this book teaches how to put rails of an elliptic nature on spiral stairs, even though they can be made out of thinner material than proper rails can.

The purpose is to enable one and all to put on a rail, and a correct one, and, to do so, timber is essential.

FIGURES 24, 25 AND 26.

An ordinary workman, without the slightest knowledge of railing, made the wreaths, from which, these photographs were taken.

It might be stated, that curves of this nature cannot be properly photographed. Some parts will appear straight, which are really curved.

Figure 26 represents a wreath made to turn at right angles, round a two-inch cylinder, and come level on a landing. This was necessary because the landing had not been built for a wreath, and was simply the landing step continued.

The best method for constructing wreaths of this nature, is, to use a block of wood squared up.

Lay out the ground plan of the rail, on the top of the block, with square and compasses, in such a way that the grain of the wood runs as in the photograph.

Cut squarely through the block for all the lines.

The lines of the landing shank are parallel with the top of the block.

The pitch of the lines for the stair shank is of course, that of the stair.

The lines on the outside and inside of the curved part can be put on with the steel rod, the curves being very short.

Whalebone is better than the steel rod.

STAIRS WITH ELLIPTIC COLUMNS

In this book the term "Spiral" is used generally. The terms "Circular" and "Elliptic Spiral" can be used with advantage to designate the nature of the column the rail is climbing.

A difficulty arises in drawing the ground plan.

Only one of the three lines, inner, centre and outer, of the rail on the ground plan can be an ellipse; and neither is necessarily an ellipse, although the ground line of the string may be.

The centre of the rail does not coincide with the inside of the string on the ground plan, and the string is usually made an ellipse; hence the centre line of the rail is not an ellipse.

Fig. 2 (c) is drawn, and the work described, as though the stair were built with the centre line of rail an ellipse, as it should be.

Whatever ellipse is used in building the stair must be adhered to in making the rail.

A rail must be of a uniform width, at right angles to a tangent to the ellipse used in building the stair.

A perpendicular to a tangent to an ellipse at the point of contact bisects the angle between the two lines which join the foci with the point of contact.

A tram, similar to Fig. 7, is necessary, standing in each focus of the ellipse used in building the stair.

The arms must slide in the sleeves on the shafts of the trams.

The sleeves must be so fastened that they are forced to move up and down together.

Pass a strong, flexible, unstretchable cord or wire from sleeve to sleeve around a pin in the pencil holder, which passes through both arms.

Place the pencil on the end of the axis minor and draw the cord taut.

Sweep the arms around, keeping the cord tight, and the ellipse to which the stair was built is made on the floor; in the case of Fig. 2 (c) it is also the centre line of the rail.

If this ellipse were not the centre line of rail it would not be drawn.

The centre line of rail would be drawn, as the inner and outer are, as will be now shown.

Attach cross pieces of equal length, one to each arm at points equally distant from the junction of the arms, Fig. 2 (c).

Remember that the above junction is always on the perimeter of the ellipse used in building the stair.

Pass a slotted bar over or under the arms and cross pieces.

The slot in the bar goes on the bolt at the junction of the cross pieces.

A hole in the bar goes on the bolt or pin at the junction of the arms.

Two holes are made in the bar for a pencil holder, for the inner and outer lines of the rail.

If the ellipse did not coincide with the centre line of the rail, a hole for a pencil holder for the centre line of the rail would also be made.

The relative position of the rail lines and ellipse can always be laid down on the axis minor, and the holes made in the bar accordingly.

A hole is made in the bar 18 inches further out than the centre line of the rail, and is thus over the walking line of the stair.

It is evident that the centre line of the holes and of the slot in the bar bisects the angle between the arms in any position they may occupy.

The rail lines can now be put on the floor, and later on the planks, when in place.

The risers of an elliptic stair do not radiate from a centre.

The rail should always be lowered at the top and raised at the bottom, so that, to a person using the stair, it would appear of a uniform height, whereas the length of the balusters is constantly varying.

Remember that the lines to plumb up from, on the drum, control the height of the rail, at all points, in all kinds of stairs, with absolute exactness, not including easings in which taste plays a part.

Bring the outer hole in the bar over the face of a riser, and mark the point; this will be on the walking line of the stair.

Make a point on the floor through the centre of the slot in the bar, and connect the points.

The connecting line will be the line to plumb up from on the drum.

Do this with all the risers.

To make the balusters of the same length, draw lines to plumb up from through the intersections of the risers with the centre line of rail.

No other change is needed.

The crosses go on as before.

Lines go on the drum as before.

A level tram head can be used as for circular spirals by fastening it to the slotted bar.

The arms will hold it level.

The work is so nearly identical with that of circular spirals, that further repetition is needless.

The Tangent System.

The following is inserted to give an idea of what has, up to the present, been considered a method of railing spiral stairs.

Only a few salient points will be touched.

Riddell's statements and admissions in his second edition will be used.

Riddell based his efforts on two fallacies:—

First: That a wreath is some part of an ellipse, or oval. whereas an ellipse is a plane figure, which does not take thickness into consideration, or even breadth, in so far as it is used by the Tangent System; and a wreath has both thickness and breadth.

On this fallacy he tried to make tangents which will to a certain extent control an ellipse, control a wreath.

Second: That a wreath of an elliptic nature would fit a spiral stair.

On these mistaken assumptions he endeavored to furnish the skilled rail-maker with a pattern or face mould, a crooked chunk of wood, a joint on each end of the chunk, and a line on each joint to square the rail with.

The previous pages demonstrate that not one of these things is essential or useful for rails of a spiral nature, and that joint ends in climbing wreaths are never square.

Riddell, page 34, says, "Let it be understood that every wreath piece is some part of an ellipse or oval, that is to say, when the plan is circular; this may be proved in various ways. For example, take a glass tumbler, and let it be about half filled with water, now place it on the table, and incline the glass from the perpendicular. It still maintains its circle. Not so with the surface of the water: it has changed from the circle to that of an ellipse."

Quite true as to the experiment, but he omitted to state what the experiment had to do with spiral stairs.

If it be maintained that Riddell's comparison is true, as to manner of climbing for instance, the author has nothing to say beyond this: Wind a piece of veneer around Riddell's tumbler, as a veneer stair string is wound around its cylinder; then tip the tumbler, noting results, or lock at Figs. 1 and 3.

The distinctions between a spiral and an ellipse have been dealt with on pages 5, 6 and 7. Read them.

Riddell, page 33, says, "The face mould being used as a pattern when any part of it happens to be just the width of the rail, let the stuff at this point be sawed full."

Riddell, page 47, says, "Note—Leave the stuff full at the centre joint of each piece, and when together clean off to width and thickness."

That is, Riddell leaves the rail maker to guess at the chunk and admits that he cannot make the joint ends.

Riddell, page 49, says, "There must be no sharp or abrupt angle at this point, nor yet too great a curve, and here it may be stated in regard to the rail, that is to say the wreath, which to produce from the level to the rake on platform stairs, may not seem to present the least difficulty. Neither there is, if appearances are considered as nothing."

"But the regular stair builder, who is always anxious to give the best effect to his work, knows that the inside curve requires the greatest care and management in order to avoid broken and crippled lines."

This is an admission that the system will not do what is wanted.

He suggests making the stair differently to enable him to put a rail on it.

He also suggests throwing the joint out of square to get out of the difficulty.

Riddell, pages 54 to 55, endeavors to get out of the difficulty by trying another method, which results in plumb joints.

He says, "The joint in this wreath, and in this case only, being plumb, may not suit the notions of some fidgety old women. The point, however, is not worth arguing; neither is it necessary to linger and show bevels to change it."

He did not seem to understand that the only joint, his bevels could work on, was a plumb joint.

Riddell, page 95, once more refers to his difficulties and says, "it has been found from practical experience that difficulty occurs in giving proper easings to a wreath which starts from level to rake."

That is, a difficulty exists, and he did ont know the cause.

Again, "This causes edge of plank for upper part of wreath to be nearly square, giving more wood than is necessary for thickness of rail, whilst at the centre joint there is scarcely sufficient."

This is an admission that the chunk furnished by the system is not thick enough, and he did not know why.

Again, "To remove this deformity the centre joint has to be thrown out of square; which may be done by a skillful hand."

This is an admission that the joints and lines furnished by the system LEAD to "deformities," that the system must be abandoned, and, "a skillful hand" must overcome the difficulties the system could not overcome.

The difficulties Riddell found insurmountable have been dealt with in the author's system, page 20.

Riddell found his greatest difficulty just after passing the end of the axis minor, at which point his slabs had to change, and with rails of an elliptic nature the pitch also changes at the end of the axis minor from an increasing to a decreasing one.

These two changes added to the difficulties dealt with, page 20, forced Riddell to abandon his system and turn over the work to a practical rail-maker.

Some tangent men contend that they finish up with a rail of a spiral nature, and not one of an elliptic nature.

See previous quotations from Riddell, page 27.

Riddell, page 32, says, "He can make the plank to assume every possible position with stuff no thicker than the width of the rail; and if called upon to state the thickness required to make the wreath square, that is, having all its corners perfect, he answers the question by obtaining a bevel that gives the greatest angle, showing, at once, the exact quantity wanted."

This contradicts quotation from page 95 as to thickness of plank.

It will be evident to one who looks at a spiral thread or who tries to use the parallel boards, Fig. 15, on a spiral thread, that the thickness of plank, necessary for a wreath of a spiral nature, depends on the length of the piece of wreath, other conditions remaining constant, and that bevels on the ends will not control the matter at all.

No work on tangent railing in the author's hands hints at using planks thick enough for rails of a spiral nature, let alone giving a method of finding the necessary thickness.

Riddell, page 66, demonstrates that the centre line of his rail is part of the perimeter of an ellipse.

The contention mentioned above is therefore contrary to the fact, so far as the Tangent System is concerned.

Consider joints: no Tangent System in the author's hands, differentiates between a plumb joint and a joint in a climbing wreath. All rail ends before moulding are represented as square or rectangular.

Figs. 21, 22 and 23 should be enough to demonstrate that, a joint cut in a climbing wreath is never square.

That, the form depends on the depth of a rail, other things being constant, and that, the deeper the rail and the smaller the cylinder, the more the joint end will vary from a rectangle.

That, a rail could be so deep that the joint would pass completely around the cylindrical part of the stair.

That, no tangent, bevel or straight line can possibly control a joint end in a climbing wreath.

That, the sides AD and BE are elliptic. That, the top AB and the bottom DE cannot both be straight, and neither can be straight unless one, on being produced, passes through the axis.

A point, to be over the ground plan of a vertical cylinder, must be on the surface of the cylinder.

A straight line can only touch a vertical cylinder in one point, unless vertical, and can only be over the ground plan at the point of contact.

No joint in a climbing wreath is plumb, and no plumb line can be placed on the face of the joint.

Therefore, no straight line on the joint can touch the cylinder in more than one point, or be over the ground plan at more than one point.

Figs. 14, 37 and 38, in "Common-Sense Hand Railing," copyrighted, 1903, pages 74, 96 and 97, show how face moulds are used on joints not plumb.

In explanation of Fig. 14, it is stated that, "The etched part shows the amount to be taken off."

It shows as usual in these systems a straight line to cut it off by.

As shown above, no straight line on such a joint can touch the cylinder in more than one point, or be over the ground plan at more than one point.

Therefore, the etched part is incorrect. It cannot be the part to be taken off, for the line should at all points touch the cylinder and be over the ground plan. See Figs. 21, 22 and 23.

Figs. 37 and 38 show how face moulds are applied to the top and bottom of the planks.

The explanation of Fig. 38 says, "The wreath is cut out to these lines." Yet the rail-maker will search in vain for any line to guide him on the end and lower side of the wreath, back as far as the mould on the under side.

He is left to guess at it.

Consider the method of unfolding steps and risers, in order to get the tangents in position.

The working out of the entire system is based on this method, the tangents being essential.

The tangents coincide with the centre line of the rail of the Tangent System, only at the ends of a wreath.

The tangent is level with the centre line of the rail on a radial line only at the end of the axis minor.

With this exception the tangents are level with the centre line of the rail on lines which are not radials, and which are at right angles to the axis major.

These lines are parallel to the axis minor.

The unfolding is done where the vertical planes, containing the tangents on the ground plan, cut the steps and risers.

The tangents for the wreath are made to suit in a rude way the top corners of the risers where they are cut by the planes.

No attempt is made to make the wreath fit the risers along the rail line.

Riddell, page 66, mentioned above, shows how the height of the centre line of the rail can be secured, but does not seem to have been able to use the knowledge properly, at least throughout the work he calls the tangents on the unfolded stair the centre line of the rail, a most obvious fallacy.

See also his failure to use the knowledge, page 112, etc.

The author has failed to find in any work on the Tangent System any use made of Riddell statements of fact, page 66.

No rule exists by which tangents can be selected which in turn will select the best ellipse, and the best part of that ellipse to use in making a wreath.

Of course nothing of an elliptic nature can fit the stair, but some would do better than others.

The whole thing is a guess.

Consider a stair whose risers radiate from the centre; a point on a tangent over a riser, with the exception mentioned above, is not level with the wreath over the same riser; see page 32, also Riddell, page 66.

Therefore, if the tangents fit, the rail cannot fit. The fact is, neither fits.

Again, consider a stair whose risers do not radiate from the centre:

Suppose, for example, the stair the same as the previous one, where each is cut by the vertical tangent planes.

The tangents for the wreath go on as for the previous stair.

The same rail is made as for the previous stair, no matter how much the stairs may vary on the rail line.

If the rail fitted one stair, it could not fit the other.

The only way out of the difficulty is by once more guessing, but in this case the guessing is on so vague a basis, that Riddell himself refuses to guess, ana says, page 70, "No written instructions can be given with any certainty."

That is, the Tangent System depends for its existence on tangents which cannot be found, and is therefore, strictly speaking, not a system in any sense of the term.

A glance at my system of railing elliptic stairs will demonstrate that Riddell failed utterly with these rails, his rail was not even built of a uniform width.

SUMMARY

The system fails to furnish a face mould for a climbing wreath.

It fails to find the chunk out of which the rail can be made.

It fails to control the end of a climbing wreath.

It fails to find tangents without which it has no existence in fact.

It got an end cut, which butted into another end cut, provided an expert draftsman put on correctly the labyrinth of lines required, and an expert workman made the end cuts correctly, which is practically an impossibility by the methods employed.

Had Riddell's efforts been successful, instead of the reverse, the result would have been only a rail of an elliptic nature, utterly unfit to go on any stair.

It is difficult to understand how anything but failure could possibly have been hoped for, from efforts based on the fallacies mentioned above.

STAIRS

At the request of a number of ordinary carpenters, the following is inserted for the purpose of guiding such men, in building a stair, so that it will permit a rail to pass from straight to circular parts, and also on the circular parts, as smoothly as possible.

For all practical purposes, it may be stated, that what is necessary to secure that result is, that the centre line of the rail should climb at the same pitch, on the circular parts, as on the straight parts.

In other words, the measurement of all steps, measured along the centre line of the rail on the ground plan, both on the straight and circular parts, must be the same.

For example,—suppose the step for the stair, of which fig. 2 is a ground plan of the rail and risers, measures 9 3-7 inches on the straight part of the stair, not counting the part of the step which projects beyond the face of the riser. Then each of the steps, which pass around the circular part of the stair (not counting the part which projects beyond the face of the riser), should measure along the circumference of the circle of the centre line of the rail on the ground plan, 9 3-7 inches.

In fig. 2, four steps pass around the circular part of the stair, which is a semicircle. Therefore the semicircle of the centre line of rail on the ground plan measures 9 3-7 x 4, or 37 5-7 inches. Therefore the radius of the circle of the centre line of rail on the ground plan would be 12 inches.

Suppose the rail 4 inches in breadth. Then the radius of the circle of the inside line of rail on the ground plan would be 12 inches less 1-2 the breadth of rail, that is 12 inches less 2 inches, or 10 inches. That is the radius of the drum, to use in making the rail, would be 10 inches.

The centre line of the balusters coincides with the centre line of the rail, and the balusters are usually set flush with the face of the string.

Suppose the baluster 2 inches thick. Then the radius of the circle for the face of the string would be 12 inches less 1-2 the thickness of the baluster, that is 12 inches less 1 inch, or 11 inches.

Another example,—suppose the stair makes a quarter turn, and only one step, that is, a platform is used to pass around the circular part. Suppose the step on the straight, as in the previous examples, is 9 3-7 inches. Then the quarter circle of the centre line of rail, on the ground plan, must be 9 3-7 inches. Therefore the radius of the circle of the centre line of rail, on the ground plan, would be 6 inches.

Suppose the rail 3 inches in breadth. Then the radius of the circle of the inside line of the rail, on the ground plan, would be 6 inches less 1 1-2 inches, or 4 1-2 inches, which is also the radius of the drum, necessary for making the rail.

Suppose the balusters 2 inches thick, and set as in the previous example. Then the radius of the circle of the face of the string would be 6 inches less 1 inch, or 5 inches.

Owing to the fact that no system within the reach of even first-class mechanics existed, in the past, for constructing continuous rails of any kind, for the circular parts of stairs, posts became very common, especially in the quarter turn, platform type of stair, last dealt with.

A knowledge of circular stair-building is not necessary with a quarter turn platform type.

Decide on the size of the cylinder for the face of the string. The size arrived at by the rule given above is best, but in no way essential; any size will do.

Draw a circle the size of the cylinder on a good floor.

Lay down a square, so that both blades will just touch the circumference of the circle, and draw two tangents. These tangents will be the ground lines of the strings. Extend the tangents to meet at the corner of the square. Draw a line at right angles to each tangent, at the point of its contact with the circle. These lines will be on the ground lines of the faces of the risers, next the platform, and if produced across the circle, will pass through its centre.

Build the foundation of the platform to suit the position of the risers, just mentioned.

Leave a corner out of the foundation; that is, make the foundation follow the tangents to their point of intersection; do not make the foundation follow the quarter circle.

Extend the floor of the platform past the corner of the foundation, and cut out a quarter circle to correspond with the quarter circle, on the ground plan. The quarter circle cut out of the corner of the floor of the platform is the corner of the platform step, and is finished as all other steps are. This quarter circle is also flush with the face of the string when finished, as will shortly be shown.

The flight of steps, above and below the platform, are straight in every particular.

When the stair is in position, fill in the corner of the platform foundation with a block, from the floor of the platform to the bottom of the string at each side, and hollowed out to correspond with the quarter circle cut out of the platform floor.

Veneer the block and the string with its circle is complete.

FIG. 3

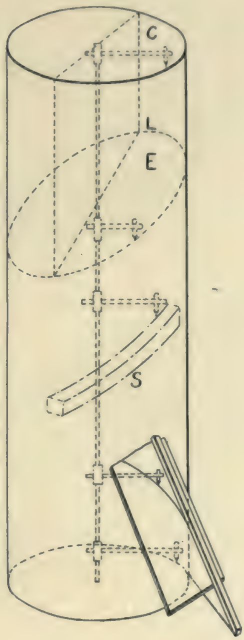
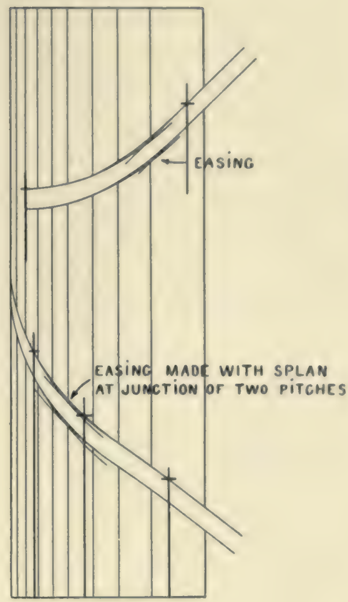


FIG. 5



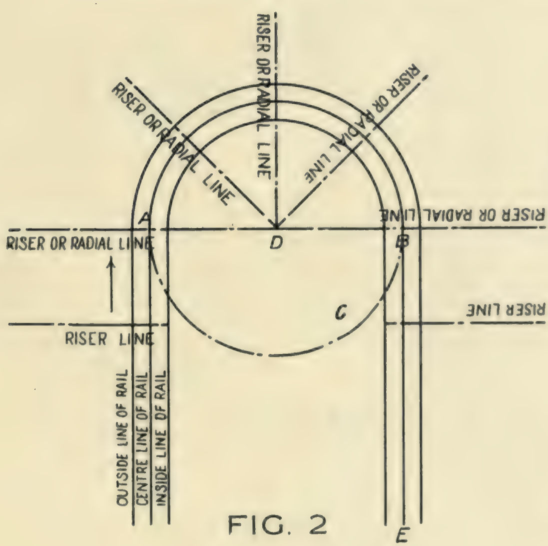


FIG. 2

FIG. 4

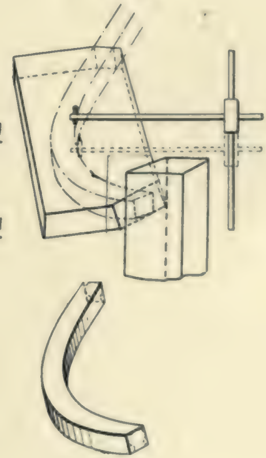


FIG. 1

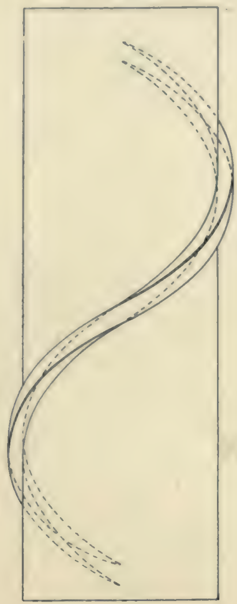


FIG. 13

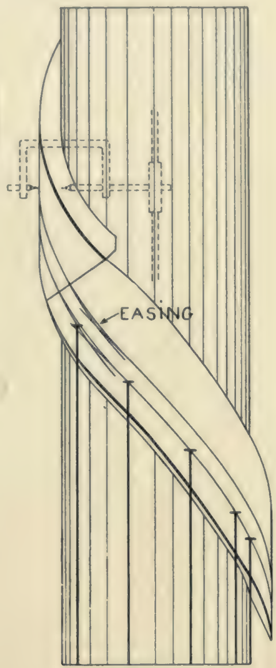


FIG. 22

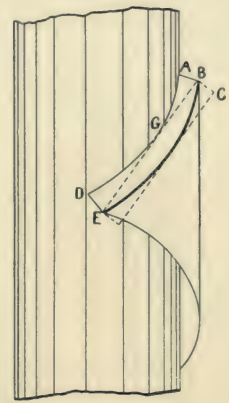
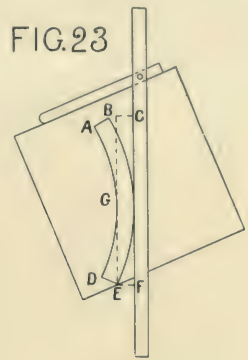


FIG. 23



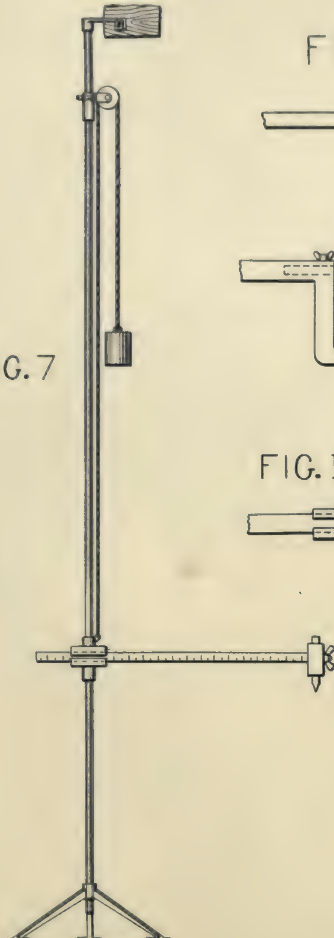


FIG. 7

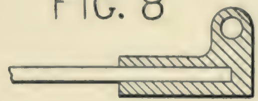


FIG. 8

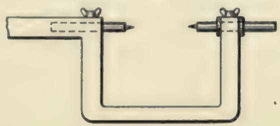


FIG. 9

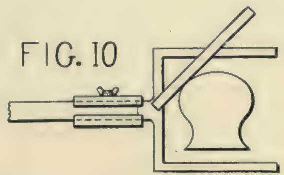


FIG. 10

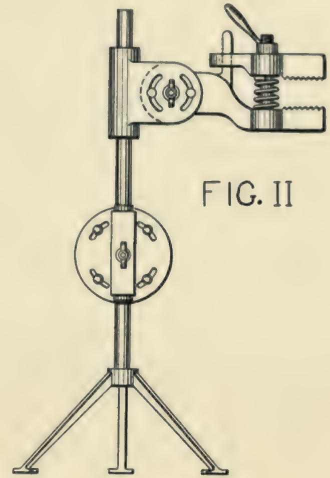


FIG. 11


FIG. 12

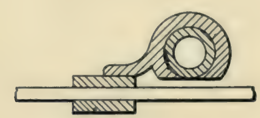
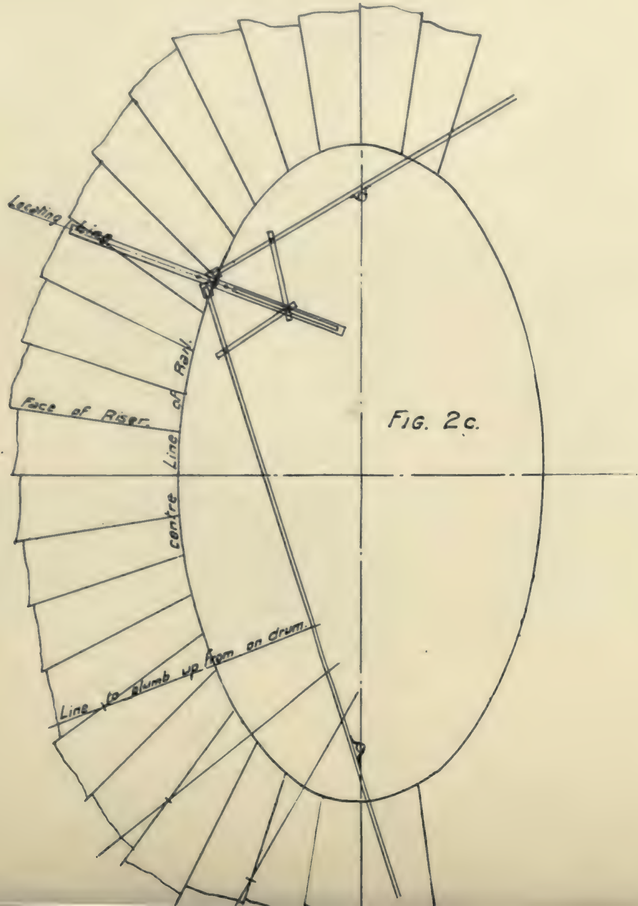
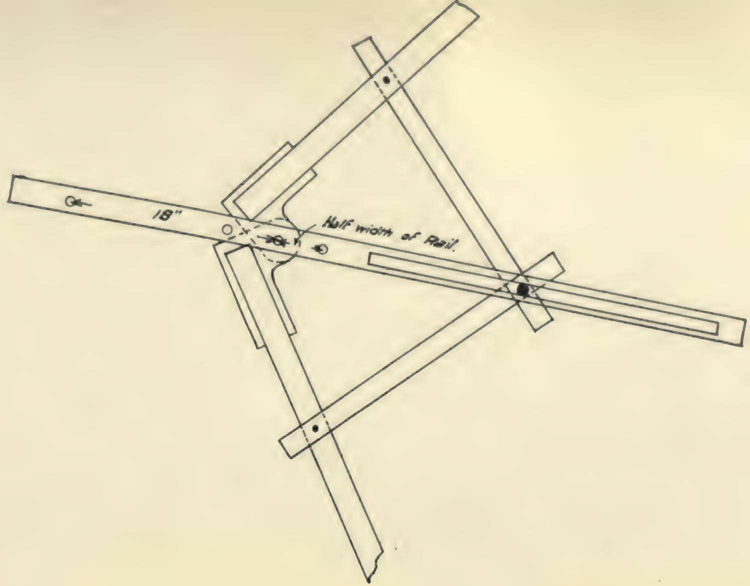


FIG. 6

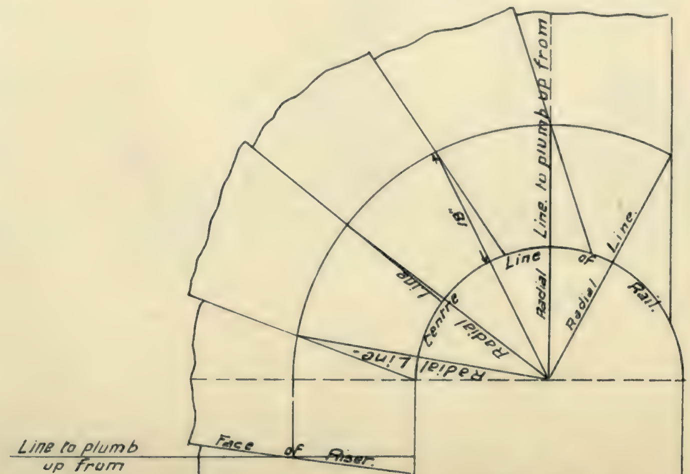


Locating Line
Face of Riser.
centre Line of Rail.
Line to plumb up from on drum.

FIG. 2c.



18"
Half width of Rail.



Line. to plumb up from
18"
Line
Centre Line of Rail.
Radial Line.
Radial
Radial
Radial Line.
Line to plumb up from
Face of Riser.

FIG. 2b.

Fig. 14

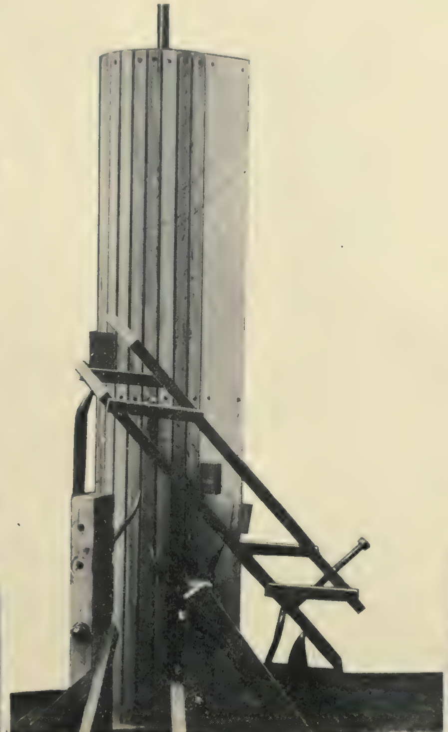


Fig. 15

Fig. 16

Fig. 17

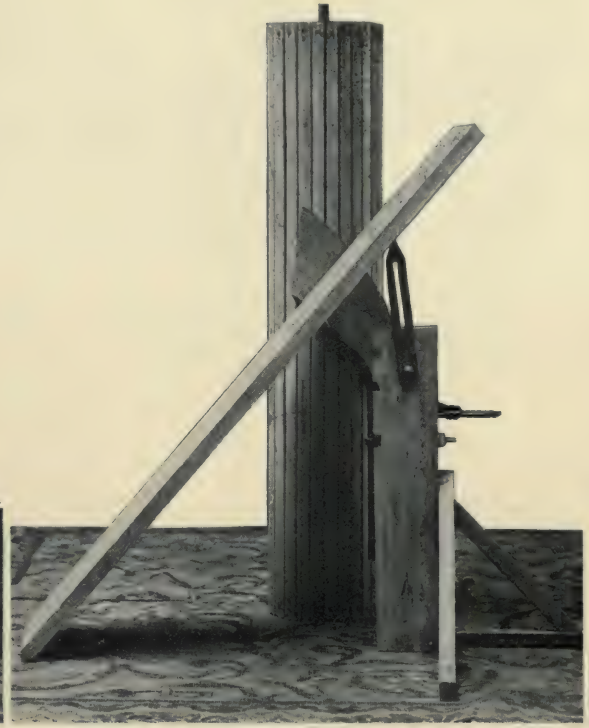


Fig. 18

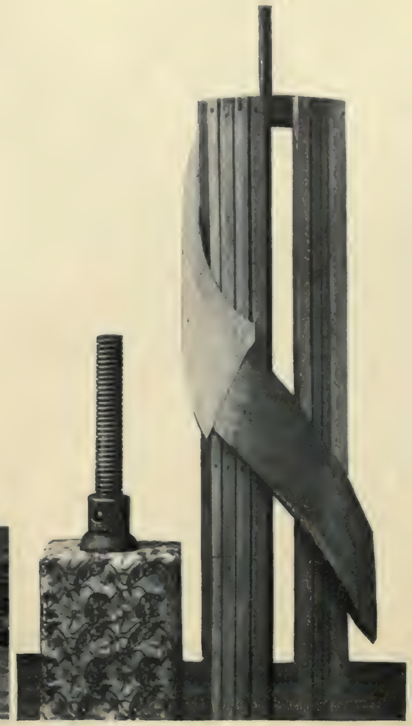


Fig. 19

Fig. 20

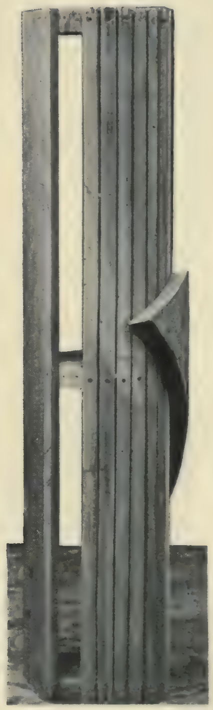


Fig. 21

Fig, 24

Fig. 25

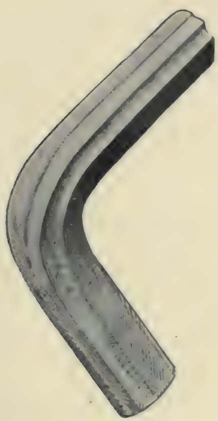


Fig. 26