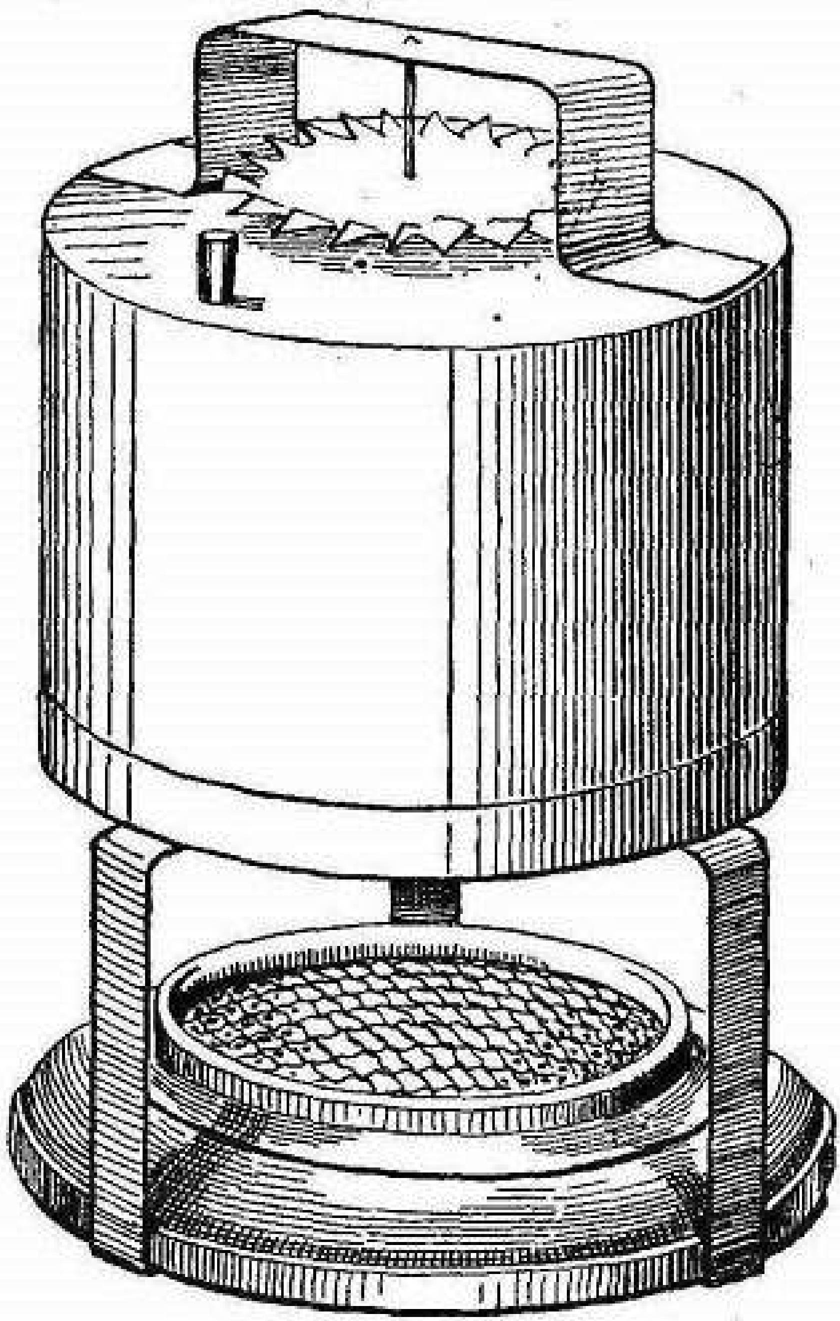

FIG. 67.—Simple steam turbine.

Steam turbines have come very much to the fore during recent years, especially for marine propulsion. In principle they are far simpler than cylinder engines, steam being merely directed at a suitable angle on to specially shaped vanes attached to a revolving drum and shaft. In the Parsons type of turbine the steam expands as it passes through successive rings of blades, the diameter of which rings, as well as the length and number of the blades, increases towards the exhaust end of the casing, so that the increasing velocity of the expanding steam may be taken full advantage of. The De Laval turbine includes but a single ring of vanes, against which the steam issues through nozzles so shaped as to allow the steam to expand somewhat and its molecules to be moving at enormous velocity before reaching the vanes. A De Laval wheel revolves at terrific speeds, the limit being tens of thousands of turns per minute for the smallest engines. The greatest efficiency is obtained, theoretically, when the vane velocity is half that of the steam, the latter, after passing round the curved inside surfaces of the vanes, being robbed of all its energy and speed. (For a fuller description of the steam turbine, see *How It Works,* Chap. III., pp.74-86.)

The turbines to be described work on the De Laval principle, which has been selected as the easier for the beginner to follow.

A Very Simple Turbine

We will begin with a very simple contrivance, shown in Figure 67. As a "power plant" it is confessedly useless, but the making of it affords amusement and instruction. For the boiler select a circular tin with a jointless stamped lid, not less than 4 inches in diameter, so as to give plenty of heating surface, and at least 2-1/2 inches deep, to ensure a good steam space and moderately dry steam. A shallow boiler may "prime" badly, if reasonably full, and fling out a lot of water with the steam.

Clean the metal round the joints, and punch a small hole in the lid, half an inch from the edge, to give egress to the heated air during the operation of soldering up the point or joints, which must be rendered absolutely water-tight.

For the turbine wheel take a piece of thin sheet iron or brass; flatten it out, and make a slight dent in it an inch from the two nearest edges. With this dent as center are scribed two circles, of 3/4 and 1/2 inch radius respectively. Then scratch a series of radial marks between the circles, a fifth of an inch apart. Cut out along the outer circle, and with your shears follow the radial lines to the inner circle. The edge is thus separated into vanes (Figure 68), the ends of which must then be twisted round through half a right angle, with the aid of a pair of narrow-nosed pliers, care being taken to turn them all in the same direction.

A spindle is made out of a large pin, beheaded, the rough end of which must be ground or filed to a sharp point. Next, just break through the metal of the disc at the center with a sharpened wire nail, and push the spindle through till it projects a quarter of an inch or so. Soldering the disc to the spindle is most easily effected with a blowpipe or small blow-lamp.

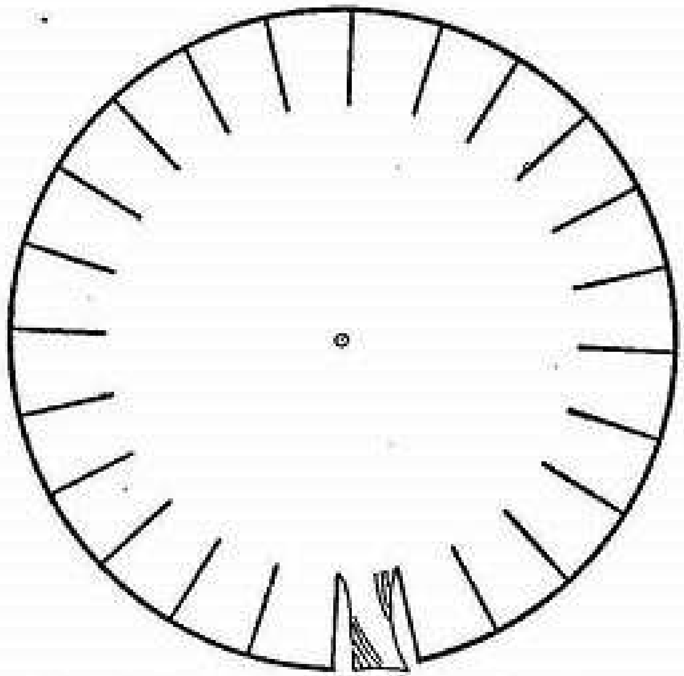

FIG. 68.—Wheel for steam turbine, showing one vane twisted into final position.

The Boiler

In the center of the boiler make a dent, to act as bottom bearing for the spindle. From this center describe a circle of 5/8-inch radius. On this circle must be made the steam port or ports. Two ports, at opposite ends of a diameter, give better results than a single port, as equalizing the pressure on the vanes, so that the spindle is relieved of bending strains. Their combined area must not, however, exceed that of the single port, if one only be used. It is important to keep in mind that for a turbine of this kind velocity of steam is everything, and that nothing is gained by increasing the number or size of ports if it causes a fall in the boiler pressure.

The holes are best made with a tiny Morse twist drill. As the metal is thin, drill squarely, so that the steam shall emerge vertically.

For the upper bearing bend a piece of tin into the shape shown in Figure 67. The vertical parts should be as nearly as possible of the same length as the spindle. In the center of the underside of the standard make a deep dent, supporting the metal on hard wood or lead, so that it shall not be pierced. If this accident occurs the piece is useless.

Place the wheel in position, the longer part of the spindle upwards, and move the standard about until the spindle is vertical in all directions. Scratch round the feet of the standard to mark their exact position, and solder the standard to the boiler. The top of the standard must now be bent slightly upwards or downwards until the spindle is held securely without being pinched.

A 3/16-inch brass nut and screw, the first soldered to the boiler round a hole of the same size as its internal diameter, make a convenient "filler;" but a plain hole plugged with a tapered piece of wood, such as the end of a pen holder, will serve.

Half fill the boiler by immersion in hot water, the large hole being kept lowermost, and one of the steam vents above water to allow the air to escape.

A spirit lamp supplies the necessary heat. Or the boiler may be held in a wire cradle over the fire, near enough to make the wheel hum. Be careful not to *over*-drive the boiler. As a wooden plug will probably be driven out before the pressure can become dangerous, this is a point in favor of using one. Corrosion of the boiler will be lessened if the boiler is kept *quite full* of water when not in use.

A Practical Steam Turbine

The next step takes us to the construction of a small turbine capable of doing some useful work. It is shown in cross section and elevation in Figure 69.

The rotor in this instance is enclosed in a case made up of two stout brass discs, D and E, and a 3/4-inch length of brass tubing. The plates should be 1/2-inch larger in diameter than the ring, if the bolts are to go outside. The stouter the parts, within reason, the better. Thick discs are not so liable to cockle as thin ones, and a stout ring will make it possible to get steam-tight joints with brown-paper packing.

The *wheel* is a disc of brass, say, 1/25 inch thick and 4 inches in diameter; the *spindle* is 3/16 inch, of silver steel rod; the *bearings,* brass tubing, making a close fit on the rod.

If you cannot get the ring ends turned up true in a lathe--a matter of but a few minutes' work--rub them down on a piece of emery cloth supported on a true surface, such as a piece of thick glass.

Now mark out accurately the centres of the discs on both sides, and make marks to show which face of each disc is to be outside.

On the outside of both scribe circles of the size of the bearing tubes, and other circles at the proper radius for the bolt hole centres.

On the outside of D scribe two circles of 2-inch and 1-11/16-inch radius, between which the steam pipe will lie.

On the inside of D scribe a circle of 1-27/32-inch radius for the steam ports.

On the outside of E mark a 7/8-inch circle for the exhaust pipe.

On the inside of both mark the circles between which the ring must lie.

Bolt Holes

The marks for these, six or twelve in number, are equally spaced on the outside of one plate, and the two plates are clamped or soldered together before the boring is done, to ensure the holes being in line. If the bolts are to screw into one plate, be careful to make the holes of the tapping size in the first instance, and to enlarge those in D afterwards. Make guide marks in the plates before separating, between what will be the uppermost holes and the circumference.

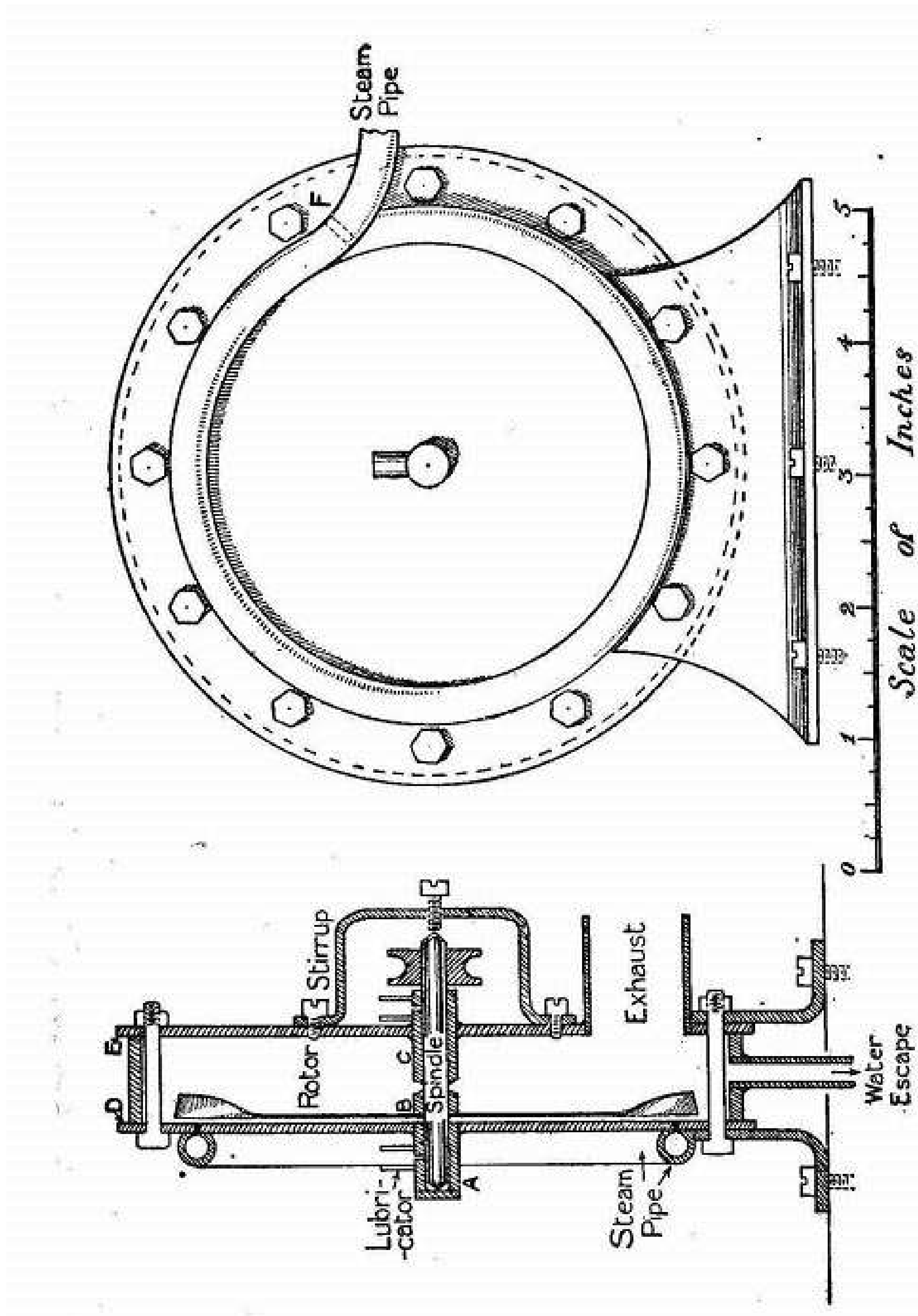

FIG. 69.—Model steam turbine, showing vertical cross section (left) and external steam pipe (right).

Bolts

These should be of brass if passed inside the ring. Nuts are not necessary if E is tapped, but their addition will give a smarter appearance and prevent-the bolts becoming loose.

Bearings

Bore central holes in the discs to a good fit for the bearings, and prepare the hole for the exhaust pipe. This hole is most easily made by drilling a ring of small holes just inside the mark and cutting through the intervening metal.

For A, B, and C cut off pieces of bearing pipe, 1/2, 1/4, and 3/4 inch long respectively, and bevel the ends of B and C as shown, to minimize friction if they rub. File all other ends square. (Lathe useful here.)

Bore oil holes in B and C, and clear away all the "burr." Make scratches on the bearings to show how far they should be pushed through the case.

Now assemble the case, taking care that the edge of the ring corresponds exactly with the circles marked on the discs, and clean the metal round the bearing holes and the bearings themselves. The last are then placed in position, with the lubricating holes pointing upwards towards the guide marks on the discs. Push the spindle rod through the bearings, which must be adjusted until the rod can be revolved easily with the fingers. Then solder in the bearing with a "Tinol" lamp.

The Wheel

Anneal this well by heating to a dull red and plunging it in cold water. Mark a circle of 1-1/4-inch radius, and draw radial lines 1/4 inch apart at the circumference from this circle to the edge. Cut out along the lines, and twist the vanes to make an angle of about 60 degrees with the central part, and bend the ends slightly backward away from the direction in which the rotor will revolve. (The directions given on p. 189 for making a steam top wheel can be applied here.)

Bore a hole in the center to make a tight fit with the spindle, and place the rotor in position, with piece B in contact on the C side. Get everything square (rotation will betray a bad wobble), and solder the three parts together with the blow-lamp.

Mount the rotor squarely by the spindle points between two pieces of wood held lightly in the vice, and, with the aid of a gage fixed to the piece nearest the wheel, true up the line of the vanes. (Lathe useful here.)

The Steam Pipe

...is 15 inches (or more) of 5/16-inch copper tubing, well annealed. To assist the bending of it into a ring one needs some circular object of the same diameter as the interior diameter of the ring round which to curve it. I procured a tooth-powder box of the right size, and nailed it firmly to a piece of board. Then I beveled off the end of the pipe to the approximately correct angle, laid it against the box, and drove in a nail to keep it tight up. Bending was then an easy matter, a nail driven in here and there holding the pipe until the ring was complete. I then soldered the end to the standing part, and detached the ring for flattening on one side with a file and emery cloth. This done, I bored a hole through the tube at F to open up the blind end of the ring.

Attaching the ring to disc D is effected as follows: --Tin the contact faces of the ring and disc pretty heavily with solder, after making poppet marks round the guide circles so that they may not be lost under the solder. The ring must be pressed tightly against its seat while heating is done with the lamp. An extra pair of hands makes things easier at this point. Be careful not to unsolder the spindle bearing, a thing which cannot happen if the bearing is kept cool by an occasional drop or two of water. A little extra solder should be applied round the points where the ports will be.

The Steam Ports

These are drilled (with a 1/32-inch twist drill), at an angle of about 30 degrees to the plate, along the circle already scribed. If you have any doubt as to your boiler's capacity, begin with one hole only, and add a second if you think it advisable. As already remarked, pressure must not be sacrificed to steam flow.

Lubricators

These are short pieces of tubing hollowed at one end by a round file of the same diameter as the bearings. A little "Tinol" is smeared over the surfaces to be joined, and the lubricators are placed in position and heated with the blow-lamp until the solder runs. To prevent the oil flowing too freely, the lubricators should be provided with airtight wooden plugs.

Escape Pipes

The pipe for the exhaust steam is now soldered into disc E, and a small water escape into the ring at its lowest point. This pipe should be connected with a closed chamber or with the exhaust at a point lower than the base of the turbine case.

Stirrup

Figure 69 shows a stirrup carrying a screw which presses against the pulley end of the spindle. This attachment makes it easy to adjust the distance between the rotor and the steam ports, and also concentrates all end thrust on to a point, thereby minimizing friction. The stirrup can be fashioned in a few minutes out of brass strip. Drill the holes for the holding-on screws; drill and tap a hole for the adjusting screw; insert the screw and center it correctly on the spindle point. Then mark the position of the two screw holes in E; drill and tap them.

Feet

... are made of sheet brass, drilled to take the three (or two) lowermost bolts, and bent to shape. *Note.* -- A side and foot may be cut out of one piece of metal. The difficulty is that the bending may distort the side, and prevent a tight joint between side and ring.

Assembling

Cut out two rings of stout brown paper a quarter of an inch wide and slightly larger in diameter than the casing ring. In assembling the turbine finally, these, after being soaked in oil, should be inserted between the ring and the discs. Put in four screws only at first, and get the ring properly centred and the bearings exactly in line, which will be shown by the spindle revolving easily. Then tighten up the nuts and insert the other bolts, the three lowest of which are passed through the feet. Affix the pulley and stirrup, and adjust the spindle longitudinally until the rotor just does not rub the casing. The soldering on of the cap of A completes operations.

To get efficiency, heavy gearing down is needed, and this can be managed easily enough with the help of a clockwork train, decreasing the speed five or more times for driving a dynamo, and much more still for slow work, such as pumping.

A More Elaborate Turbine

The turbine just described can hardly be termed an efficient one, as the vanes, owing to their simple formation, are not shaped to give good results. We therefore offer to our readers a design for a small turbine of a superior character. This turbine is shown in elevation and section in Figure 70. The casing is, as in the preceding instance, made up of flat brass plates and a ring of tubing, and the

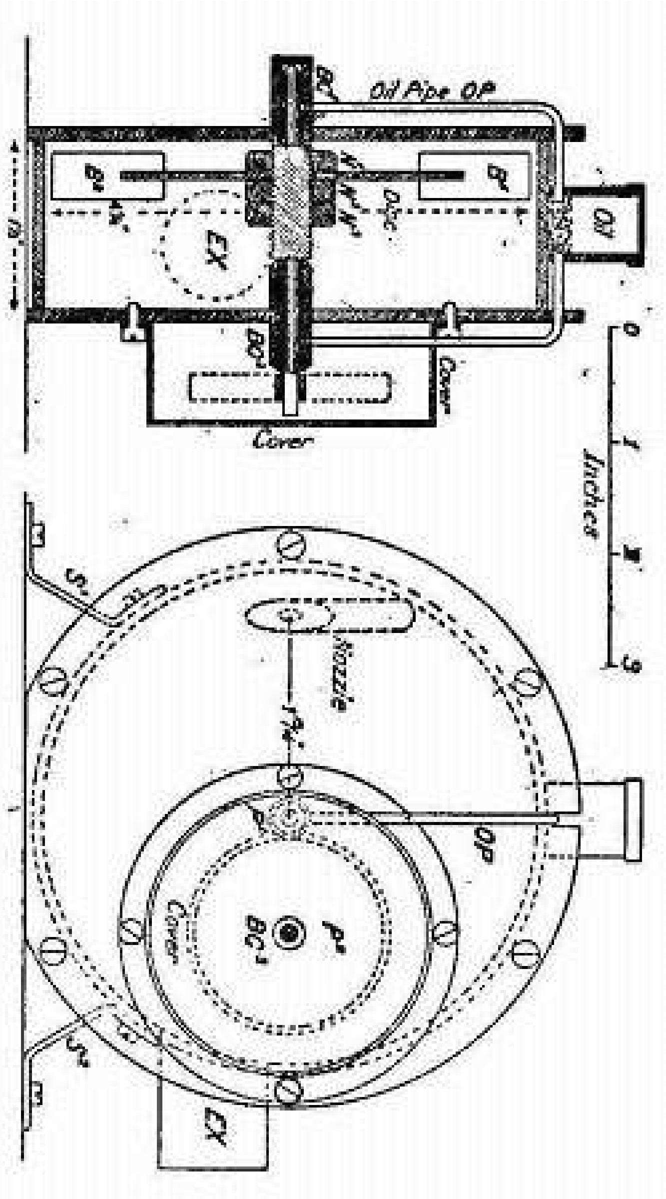

Fig. 70.—Vertical section of steam turbine with formed blades (left); outside view of turbine, gear side (right).

bearings, BG1, BG2, of brass tube. But the wheel is built up of a disc 3 inches in diameter, round the circumference of which are 32 equally-spaced buckets, blades, or vanes, projecting 5/8 inch beyond the edge of the disc. The wheel as a whole is mounted on a spindle 3-1/8 inches long, to which it is secured by three nuts, N1 N2 N3. One end of the spindle is fined down to take a small pinion, P1, meshing with a large pinion, P2, the latter running in bearings, BG3, in the wheel-case and cover. The drive of the turbine is transmitted either direct from the axle of P2 or from a pulley mounted on it.

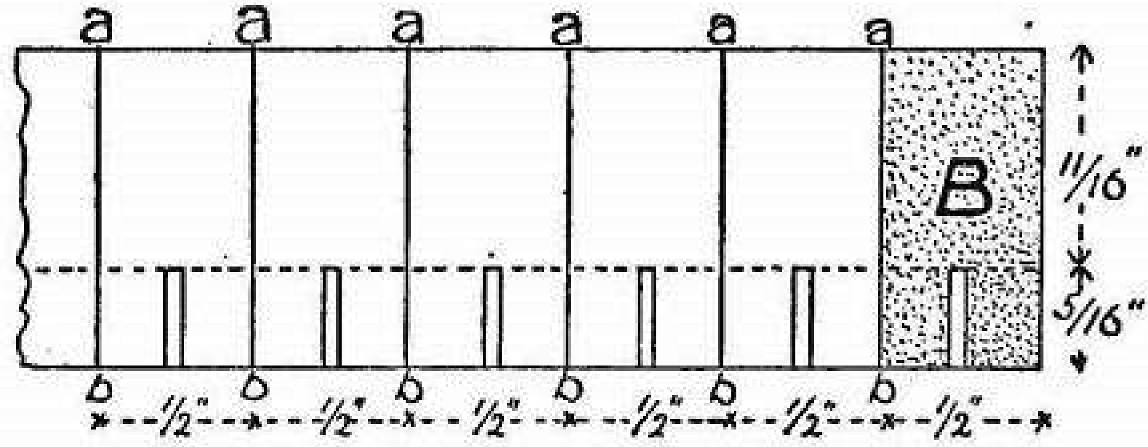

FIG. 71.—Plate marked out for turbine wheel blades. B is blade as it appears before being curved.

CONSTRUCTION

The Wheel

If you do not possess a lathe, the preparation of the spindle and mounting the wheel disc on it should be entrusted to a mechanic. Its diameter at the bearings should be 5/32 inch or thereabouts. (Get the tubing for the bearings and for the spindle turned to fit.) The larger portion is about twice as thick as the smaller, to allow room for the screw threads. The right-hand end is turned down quite small for the pinion, which should be of driving fit.

The Blades

Mark out a piece of sheet iron as shown in Figure 71 to form 32 rectangles, 1 by l/2 inch. The metal is divided along the lines *aaaa, bbbb,* and *ab, ab, ab, ab,* etc. The piece for each blade then has a central slot 5/16 inch long and as wide as the wheel disc cut very carefully in it.

Bending the Blades

In the edge of a piece of hard wood 1 inch thick file a notch 3/8 inch wide and 1/8 inch deep with a 1/2-inch circular file, and procure a metal bar which fits the groove loosely. Each blade is laid in turn over the groove, and the bar is applied lengthwise on it and driven down with a mallet, to give the blade the curvature of the groove. When all the blades have been made and shaped, draw 16 diameters through the center of the wheel disc, and at the 32 ends make nicks 1/16 inch deep in the circumference.

True up the long edges of the blades with a file, and bring them off to a sharp edge, removing the metal from the convex side.

Fixing the Blades

Select a piece of wood as thick as half the width of a finished blade, less half the thickness of the wheel disc. Cut out a circle of this wood 2 inches in diameter, and bore a hole at the center. The wheel disc is then screwed to a perfectly flat board or plate, the wooden disc being used as a spacer between them.

Slip a blade into place on the disc, easing the central slit, if necessary, to allow the near edge to lie in contact with the board -- that is parallel to the disc. Solder on the blade, using the minimum of solder needed to make a good joint. When all the blades are fixed, you will have a wheel with the blades quite true on one side. It is, therefore, important to consider, before commencing work, in which direction the concave side of the blades should be, so that when the wheel is mounted it shall face the nozzle.

To make this point clear: the direction of the nozzle having been decided, the buckets on the trued side must in turn present their concave sides to the nozzle. In Figure 70 the nozzle points downwards, and the left side of the wheel has to be trued. Therefore B1 has its convex, B2 its concave, side facing the reader, as it were.

The Nozzle

... is a 1-1/2 inch piece of brass bar. Drill a 1/20-inch hole through the center. On the outside end, enlarge this hole to 1/8 inch to a depth of 1/8 inch. The nozzle end is beveled off to an angle of 20 degrees, and a broach is inserted to give the steam port a conical section, as shown in Figure 72, so that the steam may expand and gain velocity as it approaches the blades. Care must be taken not to allow the broach to enter far enough to enlarge the throat of the nozzle to more than 1/20 inch.

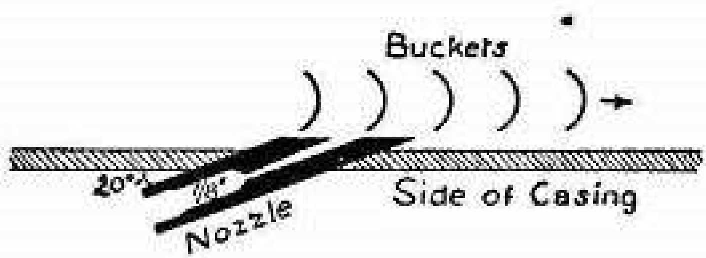

FIG. 72.—Nozzle of turbine, showing its position relatively to buckets.

Fixing the Nozzle

The center of the nozzle discharge opening is 1-13/16-inches from the center of the wheel. The nozzle must make an angle of 20 degrees with the side of the casing, through which it projects far enough to all but touch the nearer edges of the vanes. (Figure 72.) The wheel can then be adjusted, by means of the spindle nuts, to the nozzle more conveniently than the nozzle to the wheel. To get the hole in the casing correctly situated and sloped, begin by boring a hole straight through, 1/4 inch away laterally from where the steam discharge hole will be, center to center, and then work the walls of the hole to the proper angle with a circular file of the same diameter as the nozzle piece, which is then sweated in with solder. It is, of course, an easy matter to fix the nozzle at the proper angle to a thin plate, which can be screwed on to the outside of the casing, and this method has the advantage of giving easy detachment for alteration or replacement.

Balancing the Wheel

As the wheel will revolve at very high speed, it should be balanced as accurately as possible. A simple method of testing is to rest the ends of the spindle on two carefully leveled straight edges. If the wheel persists in rolling till it takes up a certain position, lighten the lower part of the wheel by scraping off solder, or by cutting away bits of the vanes below the circumference of the disc, or by drilling holes in the disc itself.

Securing the Wheel

When the wheel has been finally adjusted relatively to the nozzle, tighten up all the spindle nuts hard, and drill a hole for a pin through them and the disc parallel to the spindle, and another through N3 and the spindle. (Figure 70.)

Gearing

The gear wheels should be of good width, not less than 3/16 inch, and the smaller of steel, to withstand prolonged wear. Constant lubrication is needed, and to this end the cover should make an oil-tight fit with the casing, so that the bottom of the big pinion may run in oil. To prevent overfilling, make a plug-hole at the limit level, and fit a draw-off cock in the bottom of the cover. If oil ducts are bored in the bearing inside the cover, the splashed oil will lubricate the big pinion spindle automatically.

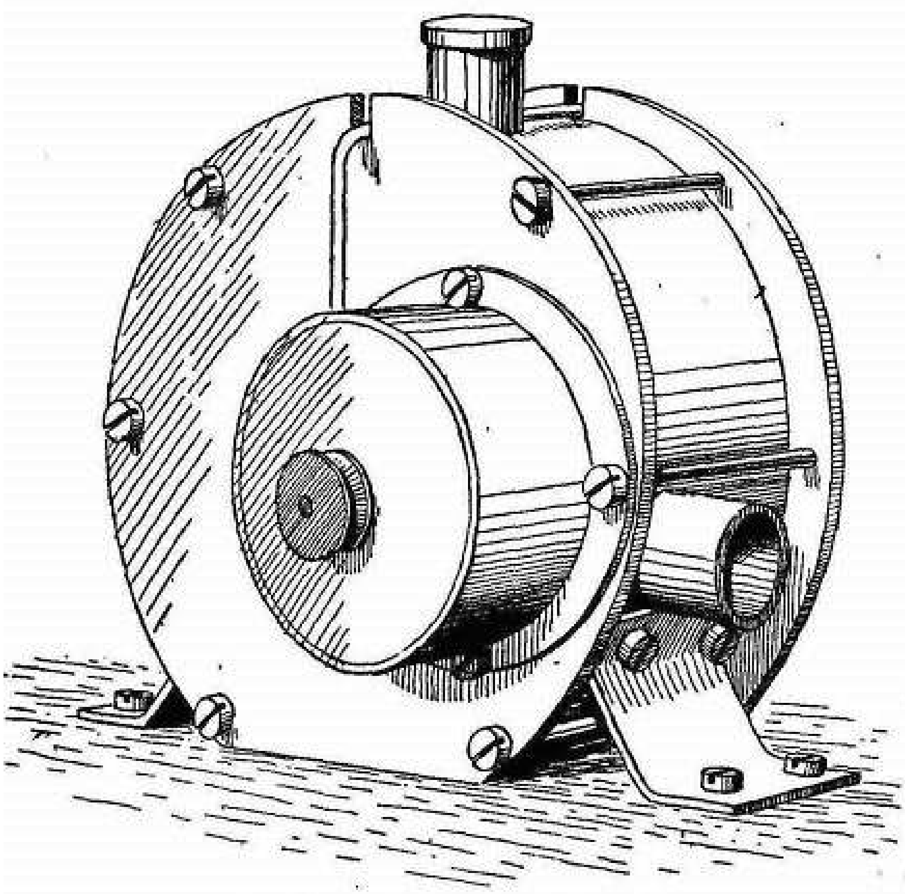

FIG. 73.—Perspective view of completed turbine.

General

The sides of the casing are held against the drum by six screw bolts on the outside of the drum. The bottom of the sides is flattened as shown (Figure 70), and the supports, S1 S2, made of such a length that when they are screwed down the flattened part is pressed hard against the bed. The *oil box* on top of the casing has a pad of cotton wool at the bottom to regulate the flow of oil to the bearings. Fit a *drain pipe* to the bottom of the wheel-case.

Testing

If your boiler will make steam above its working pressure faster than the turbine can use it, the nozzle may be enlarged with a broach until it passes all the steam that can be raised; or a second nozzle may be fitted on the other end of the diameter on which the first lies. This second nozzle should have a separate valve, so that it can be shut off.

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