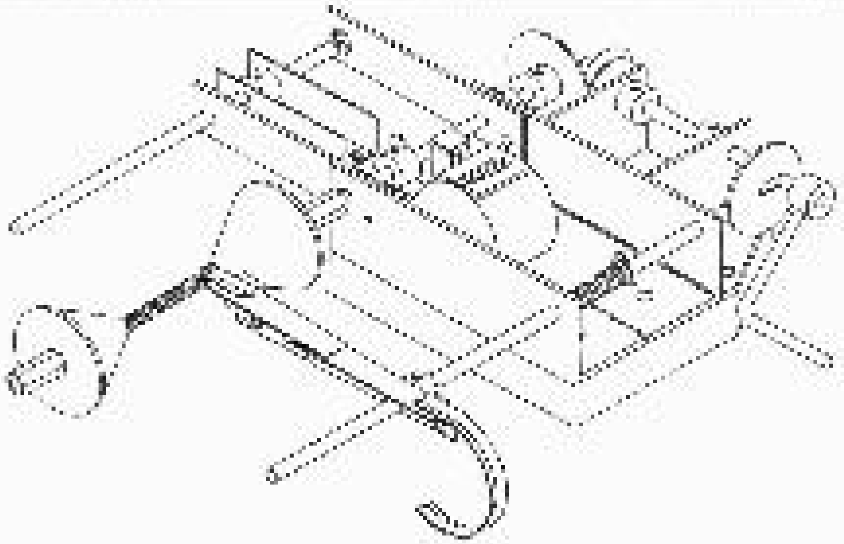

Build a

# Universal Coil Winding Machine

David J. Gingery

# Build a Universal Coil Winding Machine

Written & Illustrated
By
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## Introduction

Radio amateurs and electronics experimenters constantly work with inductance, capacitance, and resistance. In fact, the hobby has but one real goal: to understand and control these electrical phenomena.

You, as a hobbyist, need components to assemble into circuits. Coils and the inductance they provide are almost always needed. Usually you won't have a proven design that provides exact specifications. Even if you did, chances are you would have a difficult time locating the coil you need. As a result, you must wind the coil yourself adding or subtracting turns until you get it right.

It certainly is possible to hold a cylindrical form in your hands and slowly wind it with a taut wire, but completing the coil without a mishap and keeping track of the number of turns can be quite difficult. You will slip the windings, tangle the wire, be forced to answer the phone, or answer someone's "Watcha doin?" Yes, you can wind the coil by hand, but frustration may turn you into an ugly monster before you're done.

A simple coil winding machine can produce accurate, uniform coils with exactly the number of turns you want. It can also turn out complex coils that can be difficult, if not impossible, to wind by hand.

Just a few years ago, experimenters could buy two or three simple hand-operated affordable coil winders. If they're still available, they are certainly not widely advertised.

This coil winder design presented here is original only in that it adapts common, widely-available materials. Although this coil winder does provide a few new features, its design is essentially identical to that of the winders available for a few dollars years ago.

Buy a coil winder if you can, but don't let this project scare you. Although it may look quite complex, it really is not. You'll find that it is easy to build. You'll not only be proud of the coils it winds, but you will be proud of the winder, too!

With this simple, yet detailed manual you'll quickly build a machine that can wind universal and honeycomb coils, single-layer and multi-layer solenoids, close-wound and space-wound coils and pi-spaced coils such as those used for RF Chokes and transformers.

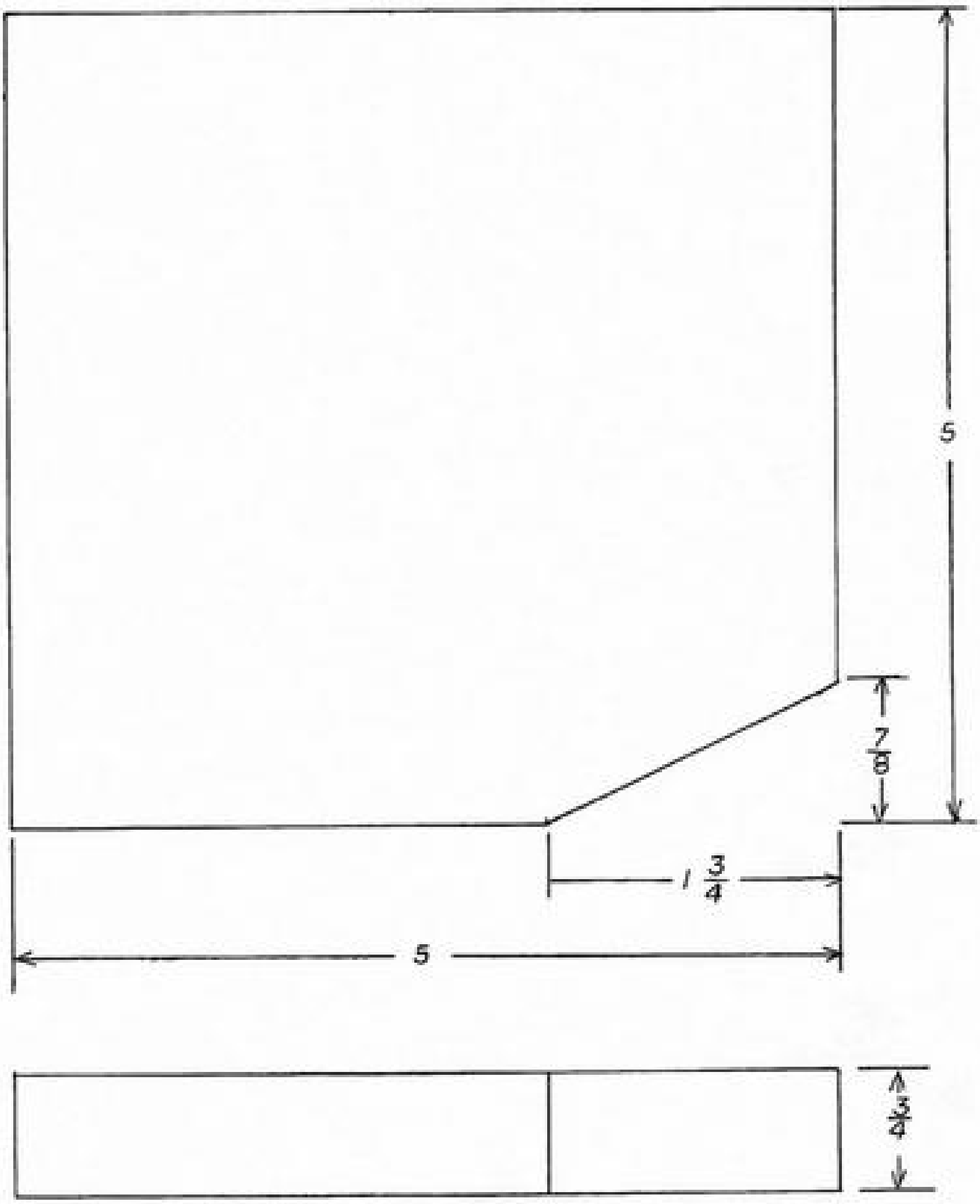
## Building the Coil Winding Machine

In this project our mechanical challenge is to mount the coil form and rotate it in a positive relationship with a counting device so that a specific number of turns can be layed on the form in a neat pattern. Quite simple in the case of a common solenoid or close wound coil on a cylindrical form. And only slightly more challenging if the turns must be spaced rather than close wound. But when the required pattern is what has come to be known as "Universal winding" the challenge is somewhat greater. Then a mechanism must be added to guide the wire in a transverse pattern while keeping count of the number of turns. In the design presented here the transverse motion is provided by a cam to convert the rotary motion of the crank shaft to the straight line motion of the wire guide. A simple friction wheel and plate accomplishes a right angle in the rotary motion to drive the coil form. And another cam operates the counter to complete the mechanism. A simple cone chuck or slit chuck holds the form and an assortment of cams provide for a variety of widths while the variable ratio friction drive allows any transverse pattern within a wide range.

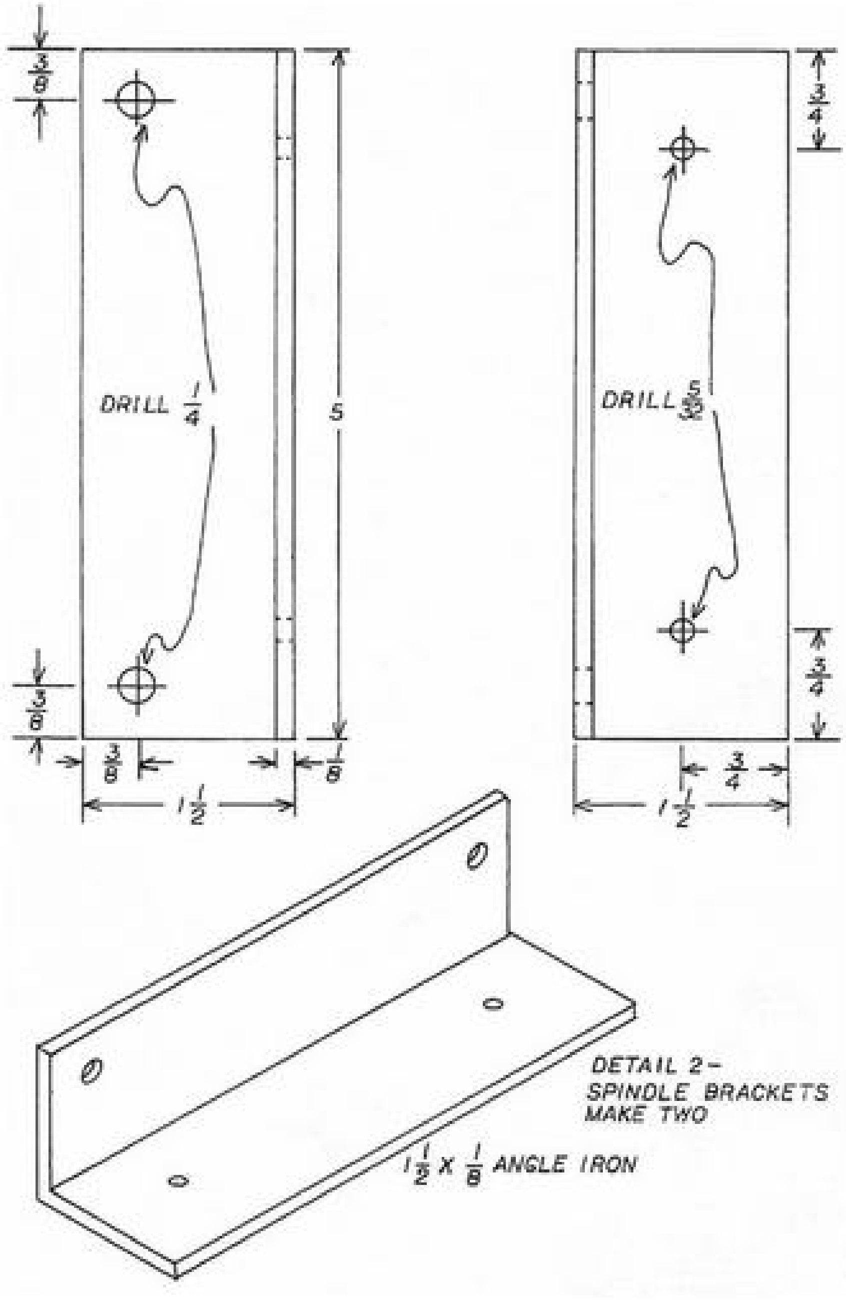
The design presented is not original except in its adaptation to common materials. Hand operated machines operating on this same principle were widely marketed for many years so the concepts are well tried. The units that were commercially available a number of years ago were built upon die-cast frames and they used die-stamped sheet metal components that are impractical for individuals to produce at home. The objective in this adaptation is to accomplish the same effects with commonly available items and without the use of machine shop equipment. A lathe would prove useful but is not at all necessary. A drill press is preferred but all of the drilling can be done with a hand drill if necessary. Also it would be preferred to braze or silver solder the cams and friction plate but these operations can be done satisfactorily by soldering with a propane torch. Alternate methods for producing and assembling the various parts will be discussed so that it becomes practical to assemble this simple machine with only a few common tools and just ordinary hand skills.

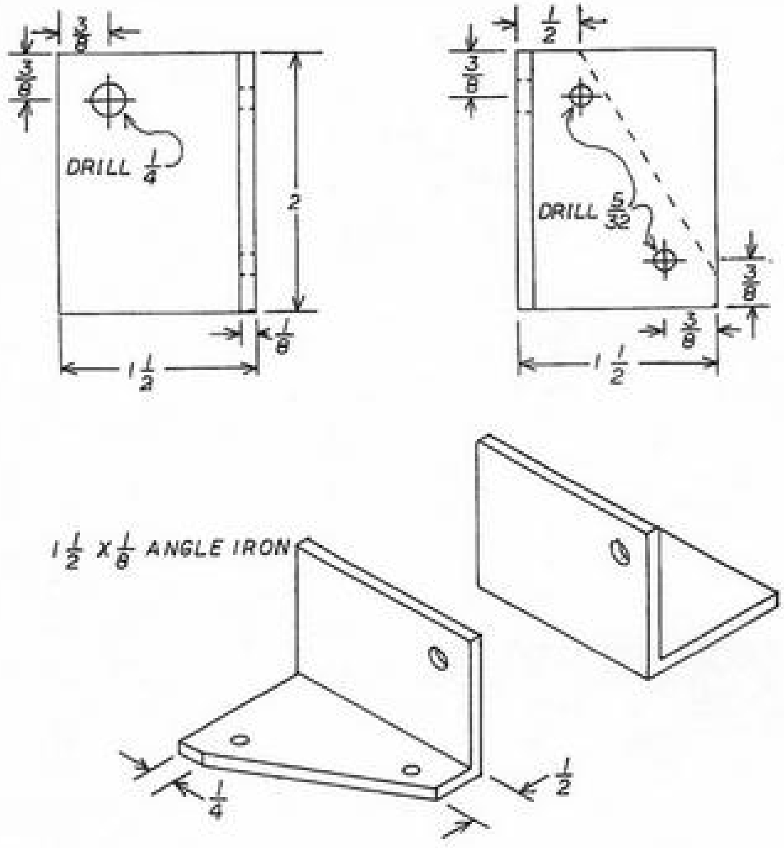
Reasonable care should be taken in all of the layout, cutting and drilling operations. But none of the operations would be termed "precision work". Hole centers should be center-punched and the drills sharp and true. The objective is for a reasonably close, friction-free fit of the spindles and cam follower, and a neat appearance on the cut edges, which are made free of burrs by filing or grinding to eliminate cutting hazards. Taken one part at a time even an inexperienced person should be able to interpret the drawings and carry out the operations. The text will be minimal but I'll try to describe in detail anything that does not seem obvious in the drawings.

Only seven simple parts are found in the main frame in addition to the screws that are used to assemble it. And the first one to make will be the wooden base as shown in detail 1. Plywood or any hardwood will be OK. And if you intend to paint or varnish the base it can be drying while you make the remaining parts.




DETAIL 1 – WOODEN BASE

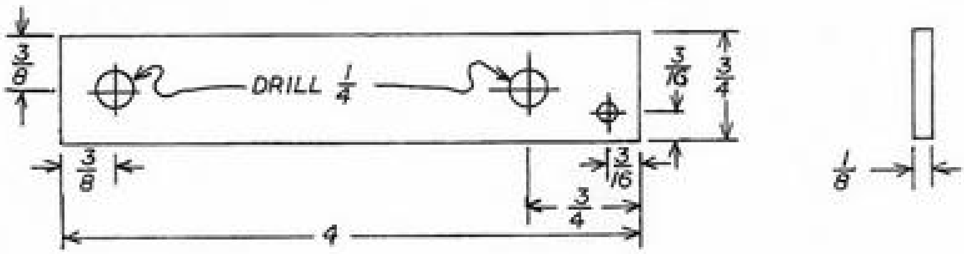

3/8
DRILL 1/4
5
3/8
3/8
1/8
1 1/2
3/4
DRILL 5/32
3/4
3/4
1 1/2
DETAIL 2 -
SPINDLE BRACKETS
MAKE TWO
1 1/2 X 1/8 ANGLE IRON



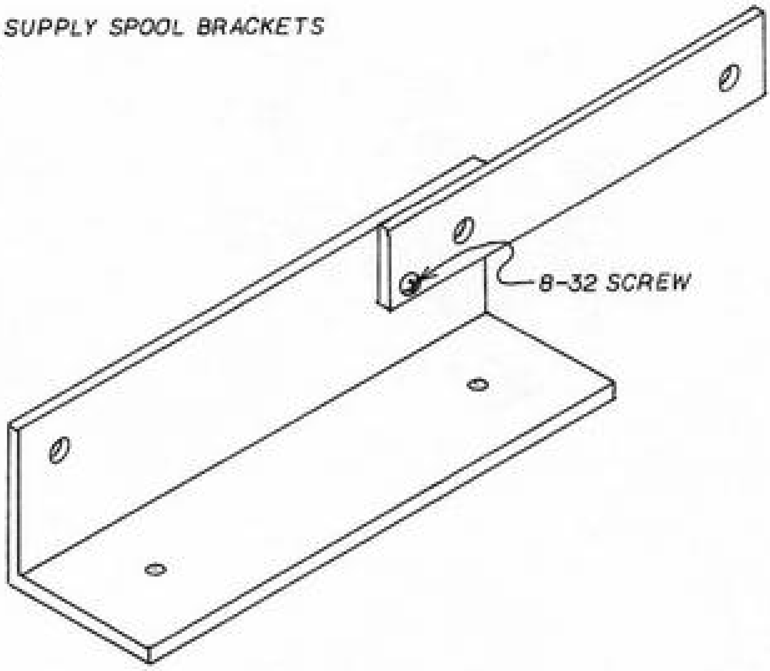

DETAIL 3– CRANK SHAFT BRACKETS
MAKE AN OPPOSING PAIR

The spindle brackets are of 1-1/2" X 1/8" structural angle iron, cut and drilled as shown in detail 2. The two 1/4" holes in the vertical leg will support the spindle and cam follower while the 5/32" holes will be used to screw the brackets to the wooden base. While alignment is not absolutely critical you should be as precise as possible with the location and size of the 1/4" holes.

The crank shaft supports are made of the same 1-1/2" X -1/8" angle iron. Again, the 1/4" holes should be as precisely located as possible. The 5/32" holes will be used to screw the parts to the base. An opposing pair is required. And only the front bracket is cut diagonally across the base flange to clear the cam travel. Shown in detail 3 above.

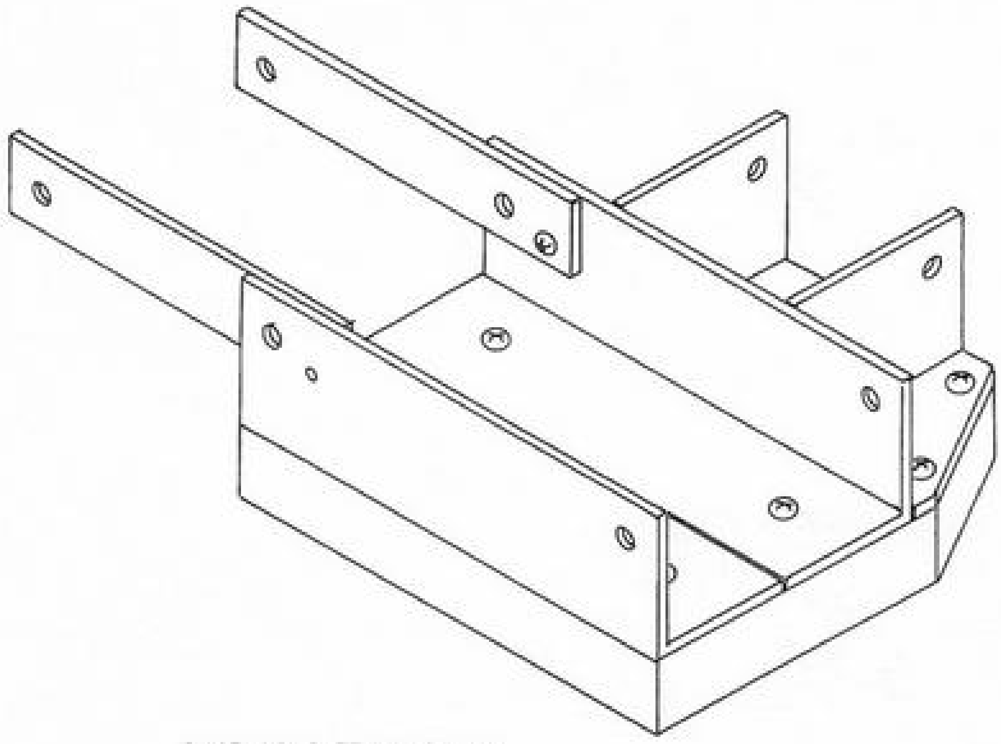



DETAIL 4— SUPPLY SPOOL BRACKETS
MAKE TWO
3/4 X 1/8 H.RS




BRACKET ASSEMBLY
MAKE AN OPPOSING PAIR

One of the improvements to the commercial design that inspired this project is the supply spool spindle. Without it there is danger of tangles in the wire as you wind so it is a worthwhile addition. Two 4" lengths of 3/4' X 1/8" hot rolled structural steel strap (H.R.S.) are drilled as indicated in detail 4 above. You can align the supply spool brackets to the spindle brackets with a 1/4" bolt and nut while you drill a #29 hole through both members. Then remove the bolt to enlarge the #29 hole in the supply spool bracket to 3/16" and tap the hole in the spindle bracket 8-32. Assemble an opposing pair as shown in the drawing above.

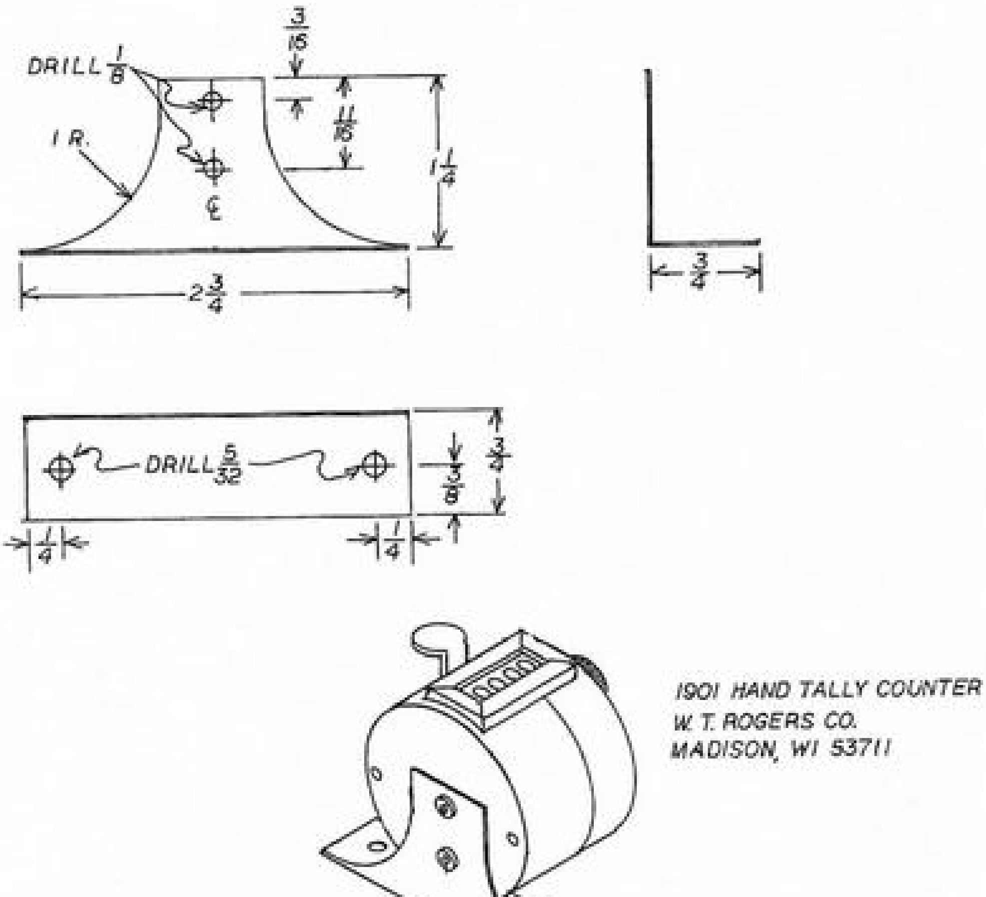


BASE–BRACKET ASSEMBLY
JOIN WITH 8 X $\frac{3}{4}$ SCREWS

The spindle brackets and crankshaft brackets are fastened to the wooden base with #8

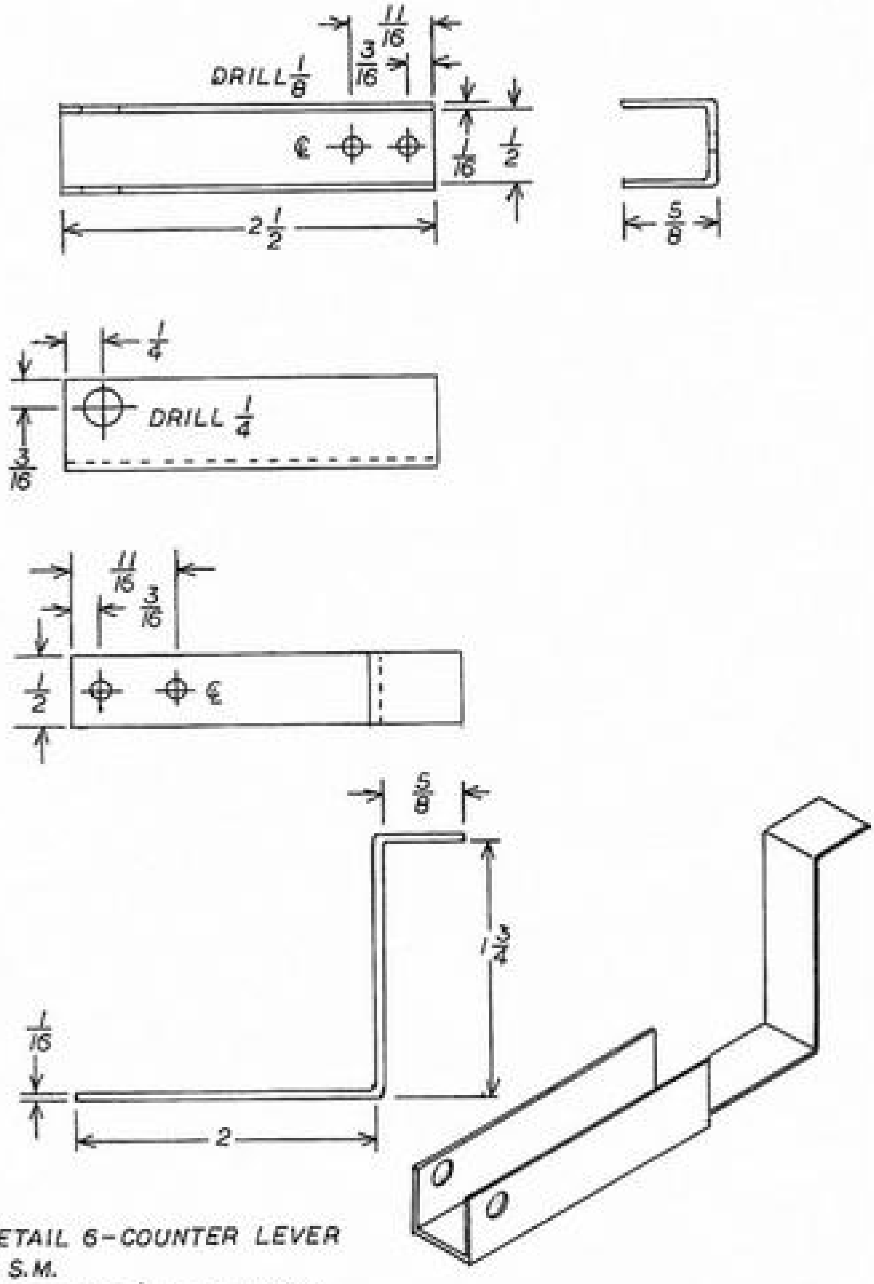
X 3/4" screws to complete the main frame assembly. It will be best to slip 1/4" rods through the holes to ensure alignment as you assemble the main frame. If you intend to paint the metal parts and varnish the wood you might disassemble the main frame and do the finishing work at this time.

One of the commercially produced winders used a simple 16 pitch worm with a 100 tooth 48 pitch stamped clock gear for the turns counter. Certainly the simplest method to imagine. But hardly the answer in the shop that has no lathe to produce the worm and considering the likely difficulty in locating the gear. Adapting a widely available hand tally counter seemed to be the practical answer in our age. And it works so nicely that I was glad the original idea proved impractical.

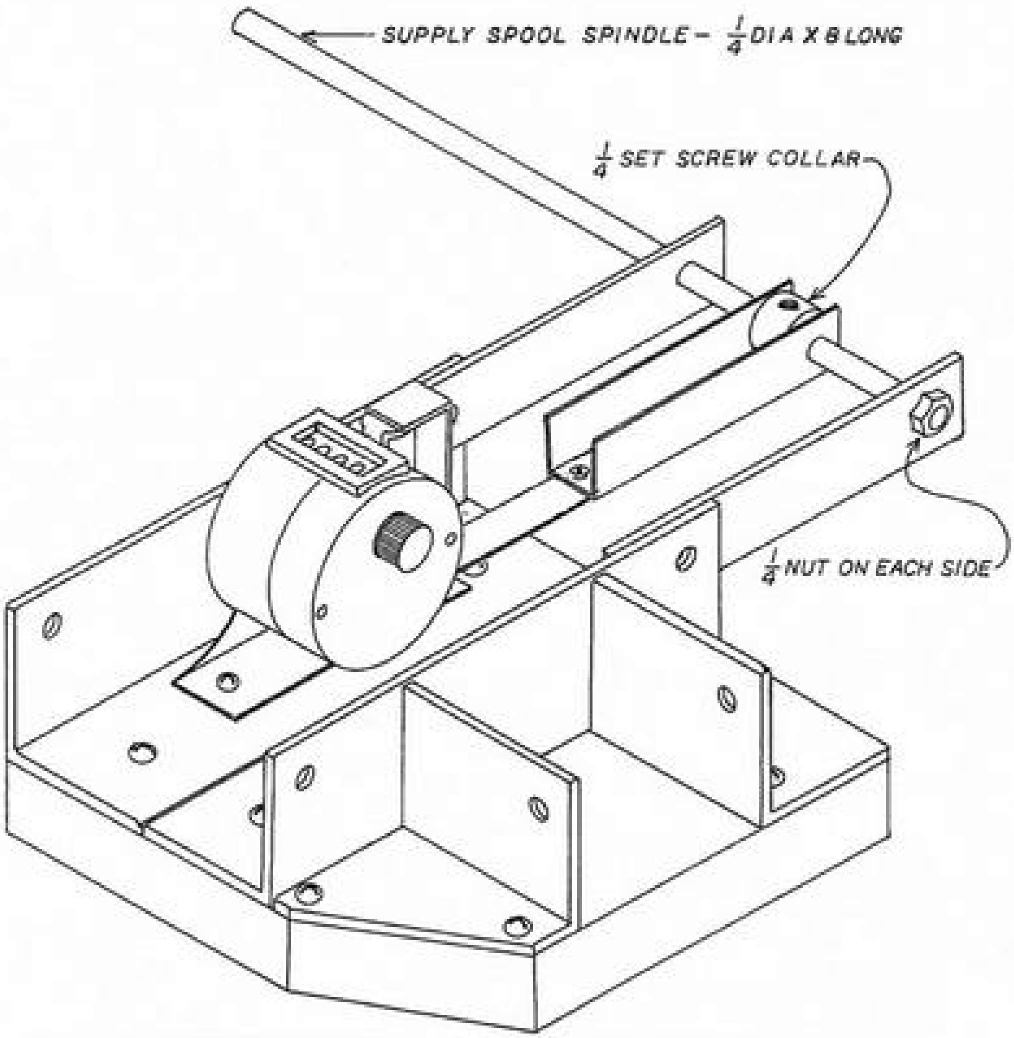



DETAIL 5- TURNS COUNTER
MAKE BRACKET OF 24 GA. S.M.
JOIN WITH POP RIVETS

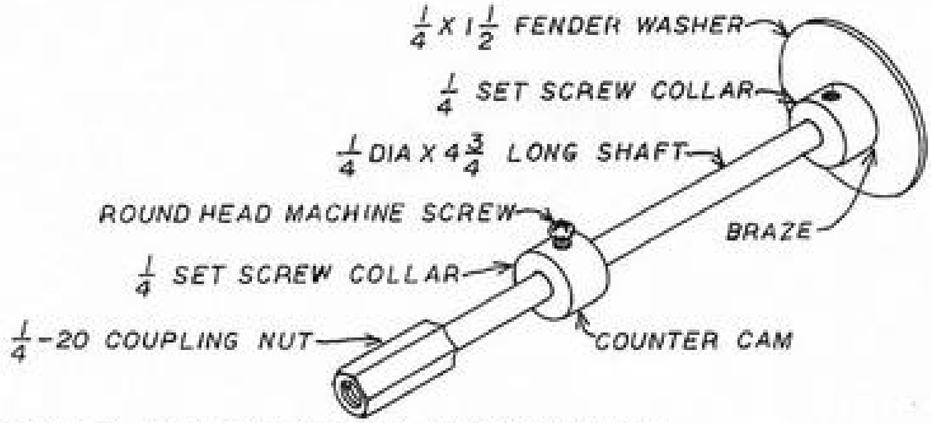
I purchased a hand tally counter from a local office supply company and added the simple bracket shown in detail 5. There are many similar units available from surplus suppliers and it would be no problem to adapt them to the same application. This particular unit has a split case joined by two small screws and the innards do not fly apart when you open the case, which you must do to drill the holes used to rivet the mounting bracket in place.



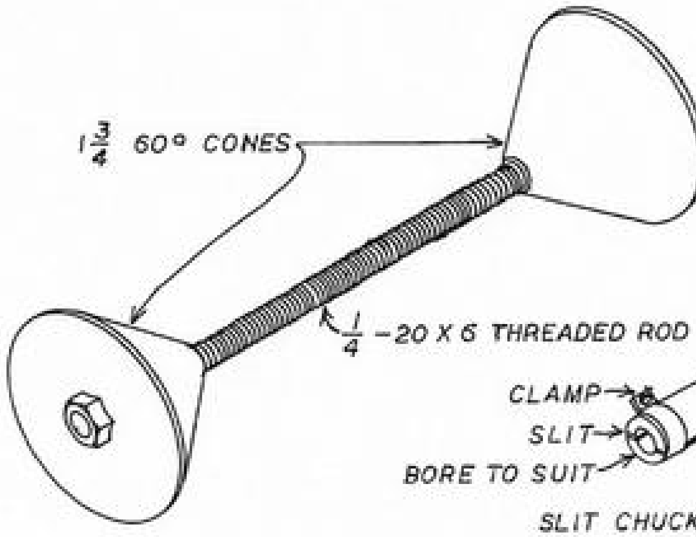

DETAIL 6-COUNTER LEVER
1/16 S.M.
JOIN WITH 1/8 POP RIVETS

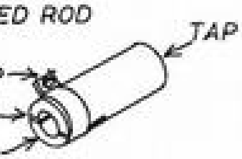



INSTALL THE TURNS COUNTER, LEVER AND SUPPLY SPOOL SPINDLE




DETAIL 7- COIL SPINDLE AND FRICTION PLATE




SLIT CHUCK

CONE MANDRELL

I removed the belt hook from the counter while it was disassembled because it was of no use in this application. And it was a simple matter to drill a couple of 1/8" holes through the case and bracket and join the parts with pop rivets. The best procedure is to drill one hole each in the case and bracket and install the first rivet. Then drill the second hole through both members to ensure perfect alignment. The rivets in this instance had to be installed from inside the case for there was scant clearance between the case wall and the counter mechanism. The heads of the rivets are much thinner than the expanded ends, And I struck the heads a blow or two with a small hammer to thin them a bit more. If you adapt a different type of counter the only requirement is to orient the button or lever so that it will be operated by the spindle cam.

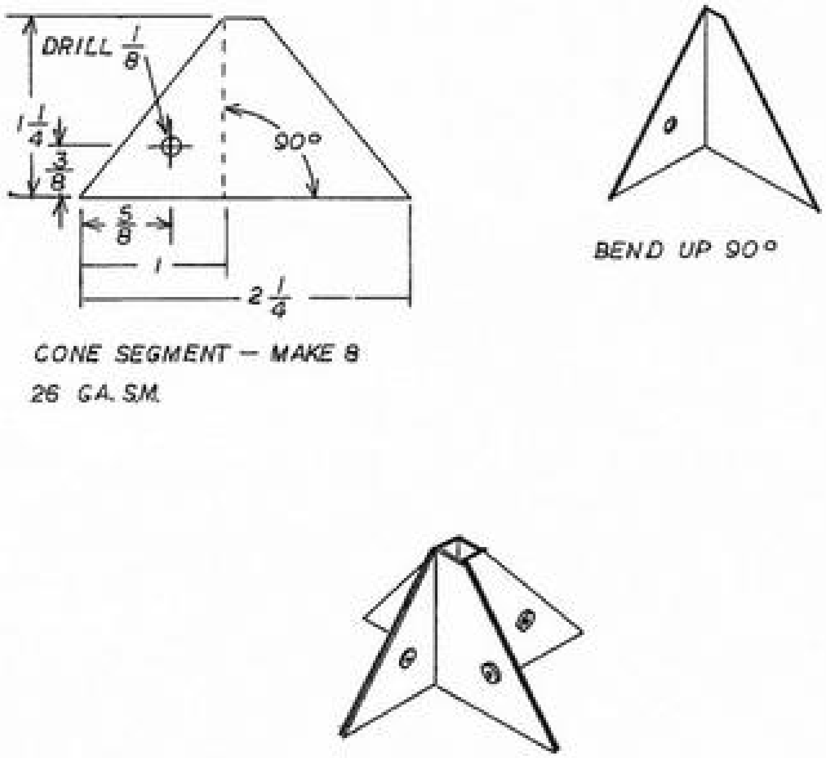
The counter lever pivots on the supply spool spindle and it is dimensioned to reach the operating button or lever of the counter. 1/16" thick sheet metal is adequate for the job. Make it as shown in detail 6 or modify to accommodate such counter as you use.

The supply spool spindle is made of 1/4" diameter rod with 1/4-20 threads cut on one end. A standard 1/4" set-screw collar is used to position the counter lever on the shaft. And a pair of 1/4-20 nuts fasten the supply spool spindle to its bracket. The counter is located to align with the lever and to clear the main spindle. Locate the two mounting holes through the holes in the bracket. Drill them #29 in the spindle bracket and tap them 8-32. Install the counter with two machine screws.

The coil spindle is made up of several simple parts. A 1/4" diameter rod 4-3/4" long is threaded 1/4-20 for about 1/2" on one end. While it would be best to cut the threads in a lathe, it can be done quite well using a guided die-stock so that the threads will be perpendicular to the axis of the shaft. These threads are for the coupling nut so a serious wobble will result if they are not quite true axially. The opposite end of the shaft has a flat filed for a length of about an inch for the set-screws to seat against.

The friction plate is made by joining a standard 1/4" set-screw collar to a 1/4" X 1-1/2" fender washer. While brazing or silver soldering is the preferred method of joining, it can be done with soft solder using a propane torch. Since both the collar and the washer are plated it will be necessary to remove the plating if you use soft solder. Use a file, grinder or abrasive cloth to remove the plating. Acid flux is required for soldering ferrous metals. And it will be best to tin the surfaces to be joined before sweating them together. If properly done the soft solder will be strong enough for this purpose. Whether brazing or soldering, avoid breathing any resultant fumes. Cadmium is especially hazardous and any such vapors are to be avoided.

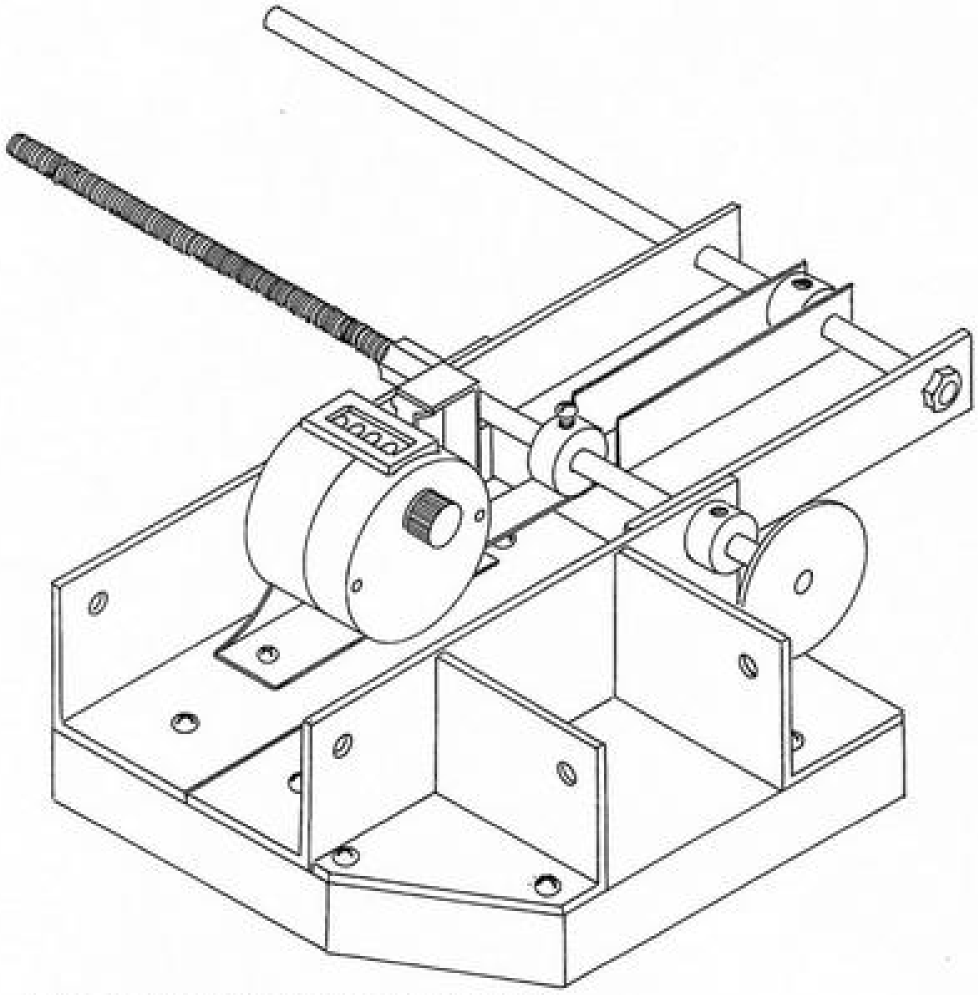
The counter cam is simply a 1/4" set-screw collar with a round head machine screw replacing the original socket head set-screw. Trim the screw to the appropriate length to both lock the collar in place on the shaft and so that the head of the screw will depress the counter lever with each rotation of the main spindle.




An additional set-screw collar is used at the friction plate end as a thrust collar to hold the friction plate against the friction wheel. Assemble all parts as shown in the next illustration.

The 1/4-20 coupling nut is used to couple the cone mandrel to the spindle and a standard 1/4-20 nut can serve as a jamb nut to lock the assembly.

The cones can be made of any workable material, with hardwood being the most practical choice for turned cones. Here a lathe would be very useful to machine the cones to shape. A very practical alternate to the wooden cones would be those fabricated of 26 gauge sheet metal as detailed in the drawing above. Note that the segments for the sheet metal cones are unequal angles so that a 1/4" square opening is left when they are assembled. Clamp the segments together and drill through the hole in the short leg of the angle and install a pop rivet for each joint. Dress away any burrs and break sharp edges to eliminate cutting hazards.



INSTALL COIL SPINDLE AND FRICTION PLATE

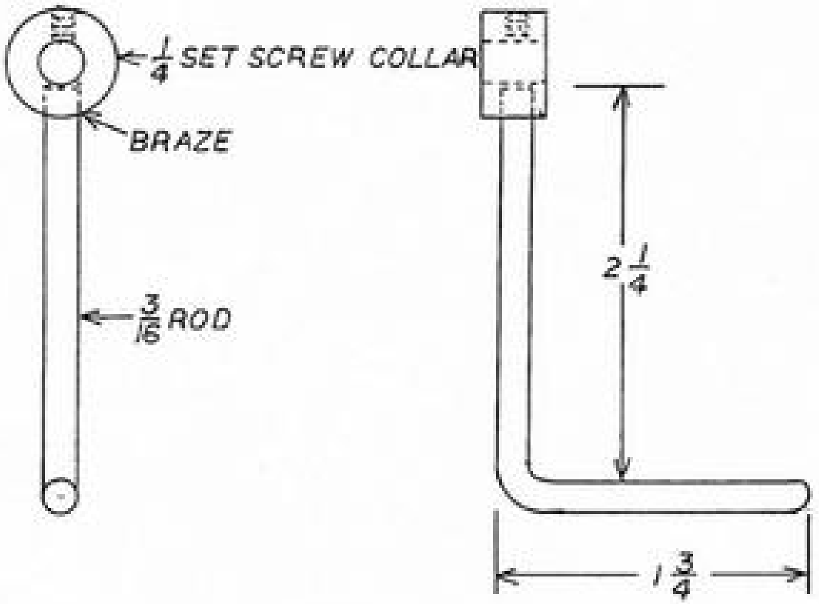
For coil forms that are too small for the cone mandrel you can improvise slit chucks, The material can be wood, metal, or plastic. Simply drill a #7 hole through a dowel or rod of practical length and tap one end 1/4-20 to fit the main spindle threads. You can then mount it on a headless bolt chucked in a drill press, hand drill or lathe and bore the opposite end to the required size to suit the form you want to wind on. Then slit the bored end with the hacksaw and install a hose clamp of appropriate size to clamp the work. A variety can be made to suit the small forms you have on hand.

The hand crank and friction wheel are a simple affair as shown in detail 8. The crank itself is bent up of 3/16" rod and brazed or soldered into a hole drilled in a 1/4" set-screw collar opposite the set-screw hole. The friction wheel can be turned of aluminum or any metal if you have a lathe. Or if a lathe is not available you could produce it with the drill press by first drilling the 1/4" bore and installing the set-screw to hold the stock on a 1/4" rod held in the chuck. An improvised tool rest would enable you to work it to its final shape and size. Yet another alternate is to obtain a drive pulley from a domestic sewing machine and close the groove with epoxy putty. Then mount it on a 1/4" mandrel held in the drill press and form the half-round groove with a file or cutting tool. The rubber tire that is used to drive the bobbin winder on a domestic sewing machine is rolled into the groove to provide the friction drive.

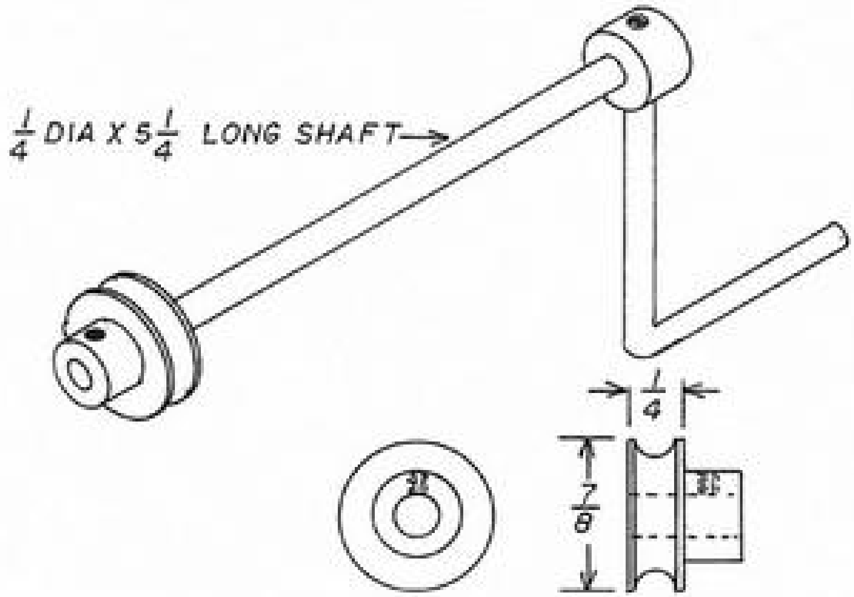
A flat is filed on each end of the crank shaft for the set-screws to bear against. And the shaft is installed as shown in detail 8 with two 1/4" set-screw collars for thrust bearings and friction wheel and crank in the appropriate positions. The pressure of the friction plate against the friction wheel is adjusted by the position of the thrust bearing collar on the main spindle. An excess amount of pressure will distort and damage the rubber tire so you want just enough pressure for effective drive.

The ratio between the crank shaft and the main spindle is infinitely variable by moving the friction wheel to any position along its shaft so that it contacts the friction plate at varying points. This is an important feature because if the ratio were simply one to one, successive turns would fall one on top of the other and the desired pattern would not evolve. While a gear drive would be more positive, it would not be possible to achieve the very fine adjustment that can be had with this simple friction drive. It requires only a little experimenting to discover the optimum adjustment for each coil job and very good results are had.

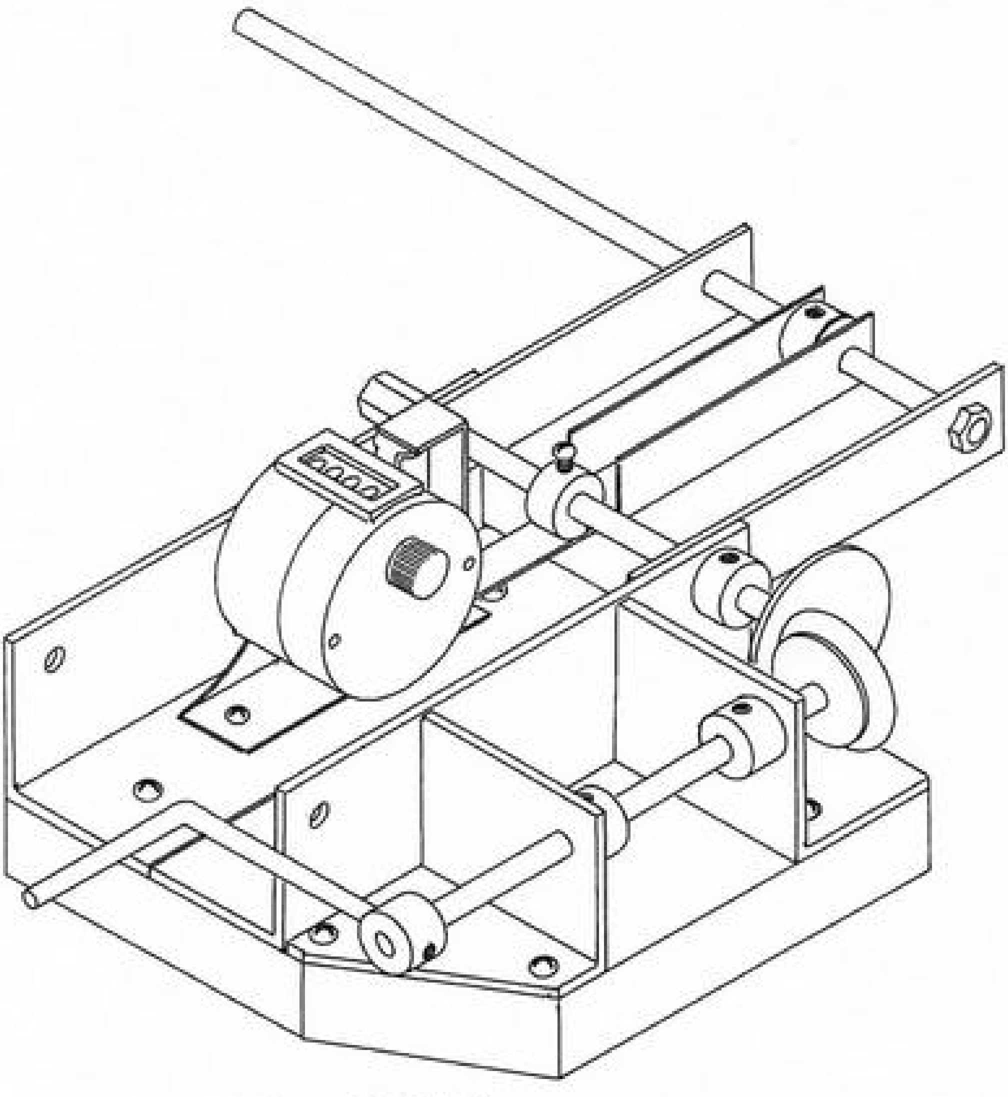
The cams are made as illustrated in detail 9. Again, while brazing is the preferred method of joining the cam plates to the set-screw collars, the job can be done effectively by soft soldering. The cam plates are 1/4" X 1-1/2" fender washers with the set-screw collar hubs mounted an appropriate amount off center. I made my set in increments of 1/8" to 3/4" and that is a rather broad range for all ordinary work. Of course any size between can be made and a self supporting universal coil as small as 3/32" wide is not too difficult to wind. 3/4" may be the practical limit to width for reasons we will discuss later. It proves generally easier to elongate the center hole in the washer with a round file than to try to drill a partial hole off center. And the set-screw collar can be held in position on the cam plate with a 1/4" bolt while brazing or soldering.



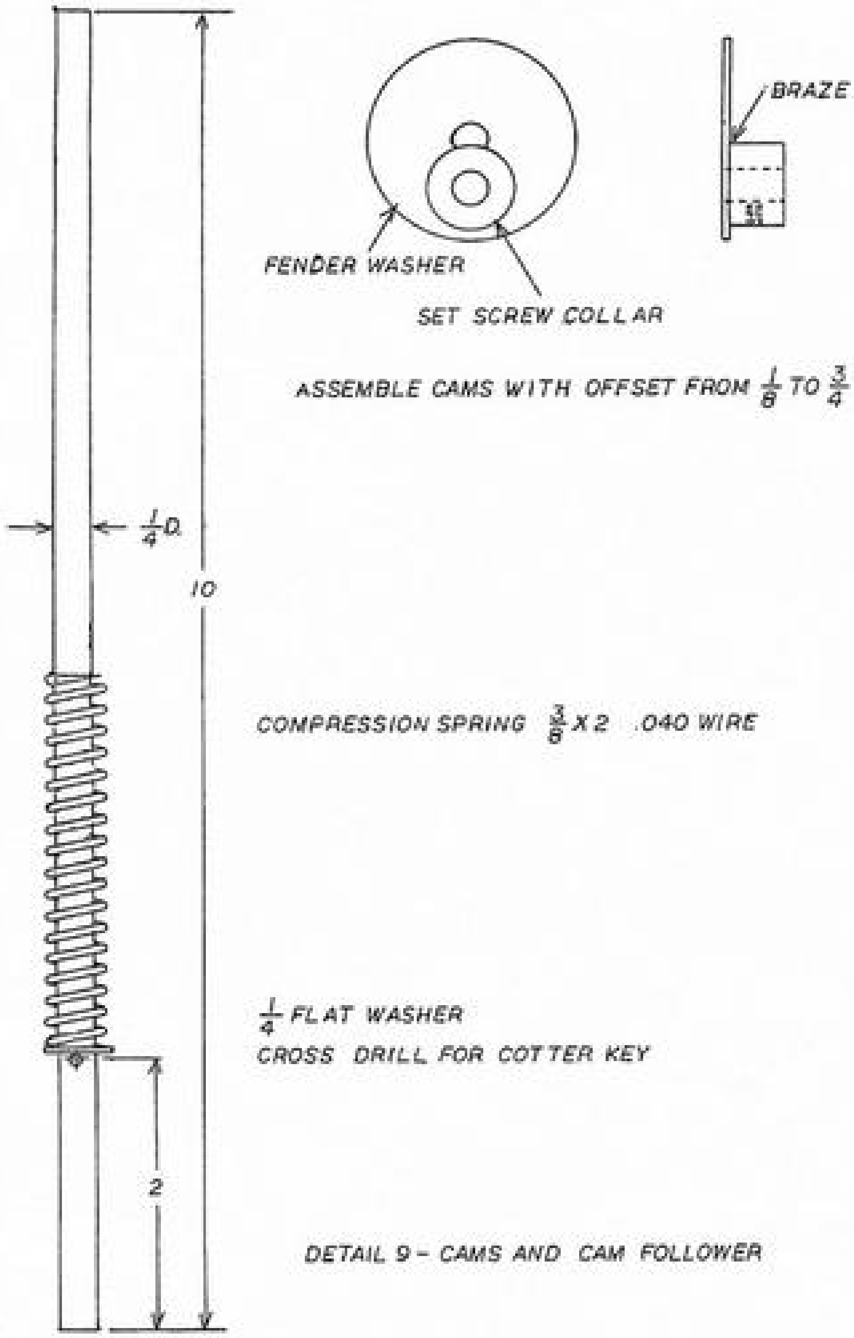

CRANK



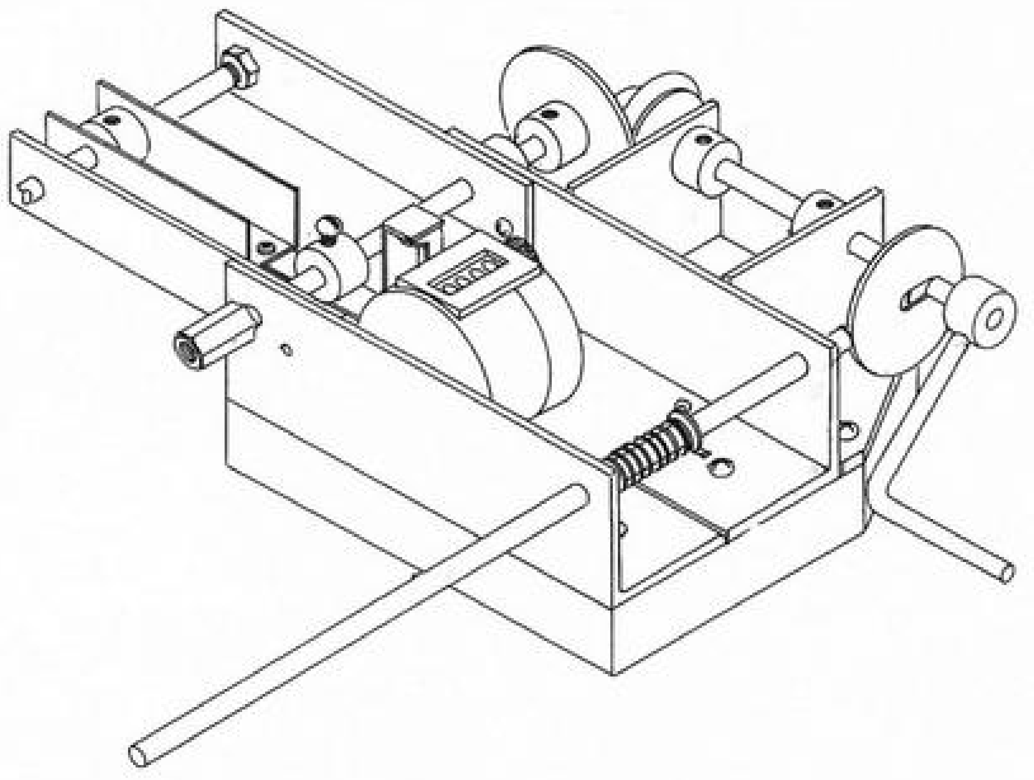

DETAIL 8— CRANK/CAM SHAFT



INSTALL THE CRANK/CAM SHAFT

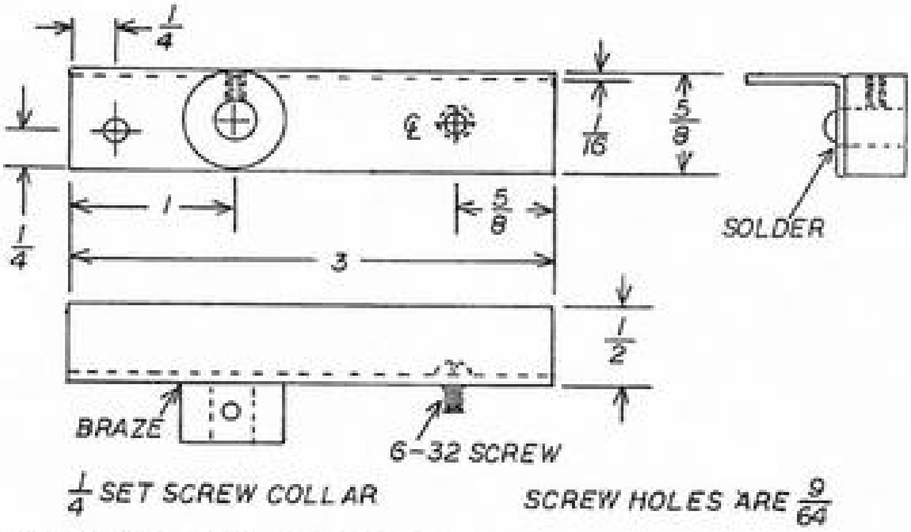



DETAIL 9 - CAMS AND CAM FOLLOWER

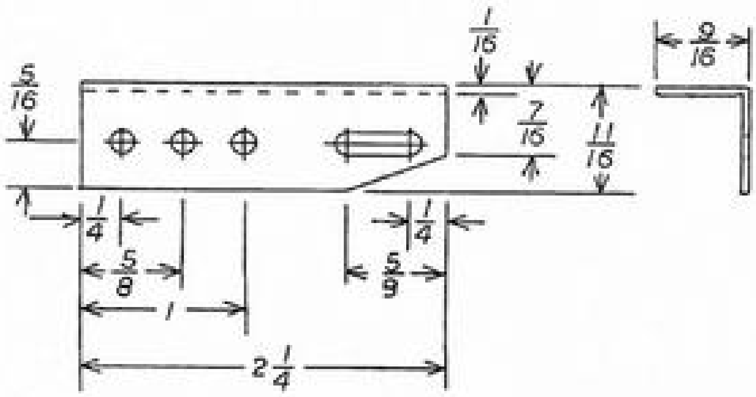


INSTALL CAM AND CAM FOLLOWER

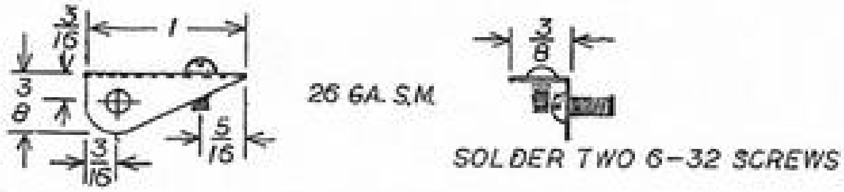
The cam follower is simply a 10" length of 1/4" rod with a small hole cross-drilled 2" from one end for a cotter key. A compression spring over the shaft forces it to follow the shape of the cam so that it travels back and forth to carry the wire guide across the coil form as it rotates. Install the follower with its spring, washer and cotter key as shown in the drawing above.




WIRE GUIDE ARM – CLAMP SECTION



WIRE GUIDE ARM – EXTENSION



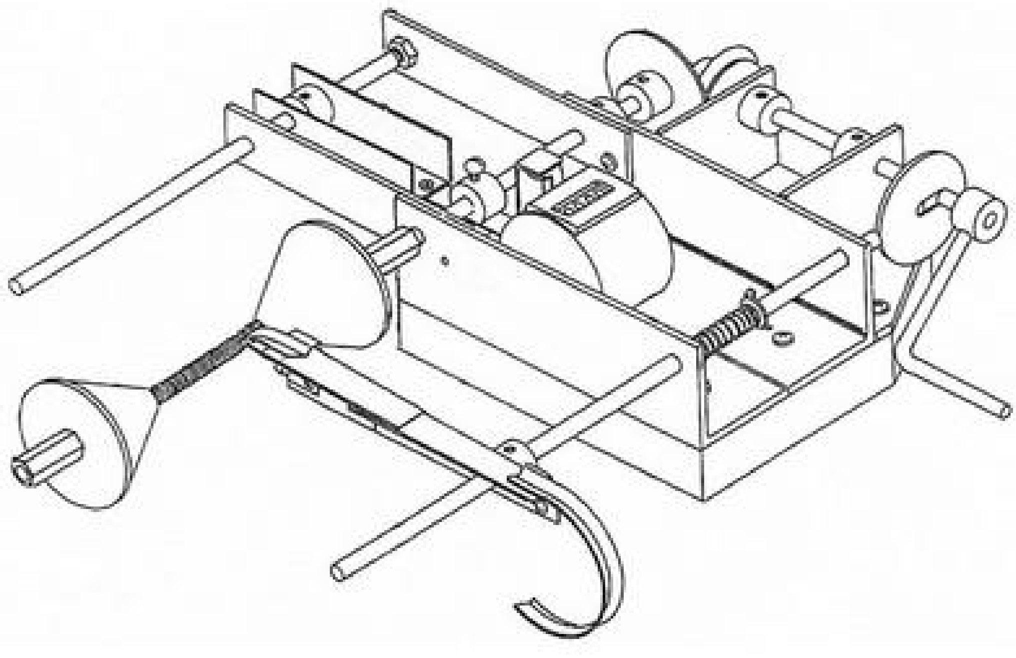

WIRE GUIDE LOOP BRACKET

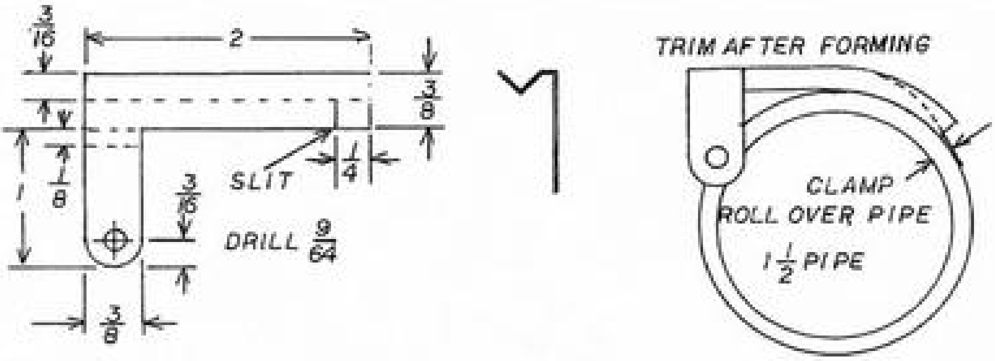
The wire guide is made up of several simple parts beginning with the clamp section. Its length is made adjustable so that the machine can accommodate any diameter of coil form. And it is held in position on the cam follower by the set-screw collar brazed or soldered to it. The machine screws are soft-soldered in place so that a nut driver can be used to adjust the length of the arm and position of the toe piece and loop bracket. Make the guide arm, extension and loop bracket as detailed in the drawings above and assemble them loosely.

The toe piece and heel piece are cut out from 26 gauge sheet metal as shown and then bent to the profile indicated to form the groove. Then they are clamped to a length of 1-1/2" pipe with vise-grip pliers or other means and rolled over the pipe to form the partial arcs. After forming, the slit portion can be cut away and the ends dressed up as required. The heel piece is left to nearly its full length but the toe piece is shortened and its end trimmed to a graceful blunt point as indicated in the drawing.

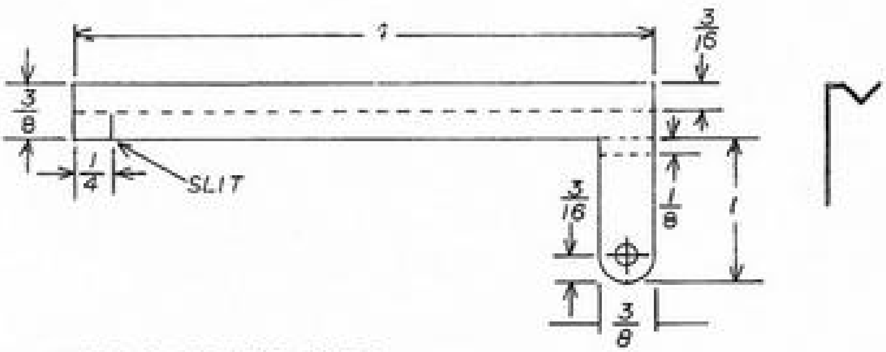
The wire guide loop is made from a common paper clip bent to appropriate shape. Its function is to form an eye that holds the wire in the groove of the toe piece so that it is drawn back and forth uniformly as the form rotates. Naturally every surface that contacts the wire must be very smooth so that the insulation is not damaged.

The entire guide is assembled as indicated in the drawing and it is installed on the follower to complete the machine.

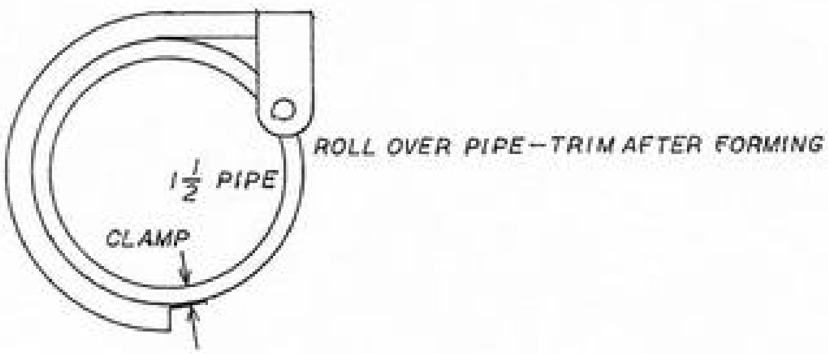


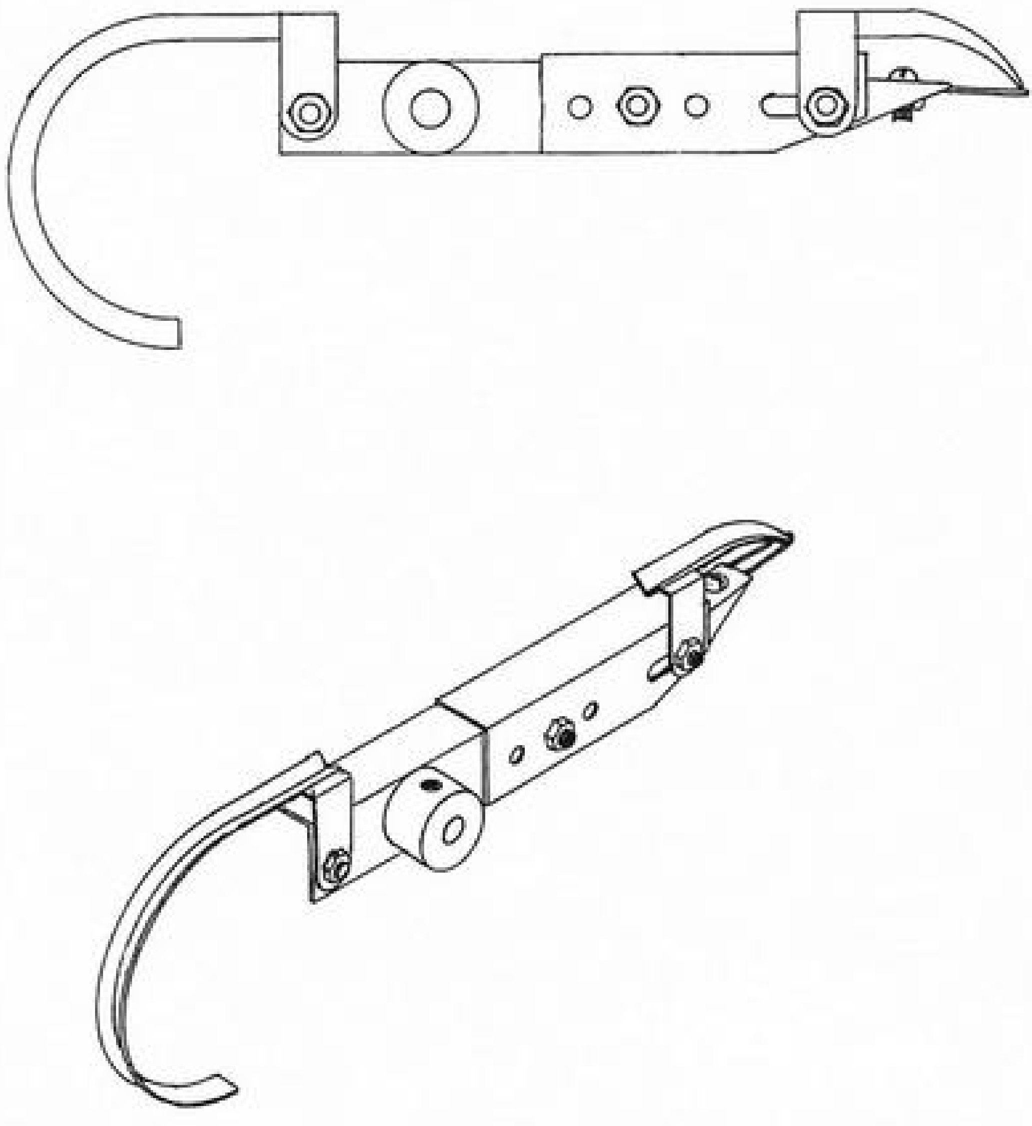



WIRE GUIDE TOE PIECE




WIRE GUIDE HEEL PIECE





WIRE GUIDE ASSEMBLY

**Coil Winder Operation**

For winding simple solenoid coils, close wound coils and layer or random wound coils the cam is removed so that the wire can be guided by hand. Spaced winding can be done by winding on the appropriate sized wire or cord with the coil and later removing it to leave uniform space between the windings.

Honeycomb coils are done in the same manner as universal coils except that the spacing and pattern is coarser. For honeycomb and universal coils each turn traverses the entire length of the coil and crosses other turns diagonally instead of parallel in order to reduce distributed capacitance. This is the function of the wire guide as it is moved across the length of the form by the cam and follower.

The practical limit to the helix angle of the turns seems to be 75 degrees or less so wider coils must also be larger in diameter. A design alternate to a single wide coil can be a row of narrow coils in series such as the familiar "pi-spaced" coils used as R F chokes.

While small gauge enameled wire is practical for narrow coils it proves a difficult task to wind a wide coil with anything but covered wire. And some adhesive agent must be used to hold the turns in place after they have been layed on. The old standby was resin dissolved in alcohol. But any of the modern very fast drying adhesives might work as well. Some experimenting will be required.

It is difficult to find covered wire in the modern market so you may have to salvage R F coils from junked radios, TV's and other electronic equipment. It may be helpful to wind a strand of thread along with the coil turns to provide some friction to hold turns in the desired pattern.

The base layer must be carefully layed to establish the pattern and shape of the coil. It helps to provide a sticky surface on the form such as a piece of masking tape with the adhesive side out.

Tension should be the minimum to conform the wire to the shape of the form. Excessive tension can distort the pattern and possibly break the wire. Very light pressure can be applied to the supply roll by the finger or an adjustable spring loaded brake pressing against the supply roll.

Coil forms of any diameter and length can be made over a waxed dowel or rod by winding a narrow strip of card stock in a spiral over the form and following it with another strip spiralled in the opposite direction and glued over it. The wax prevents a glue bond so that the finished form can be pulled off the rod. A coat of polyester resin will strengthen and seal the form. Almost any cylindrical shape of insulating material can be used as a coil form. But of course some materials are better than others and the Q of the coil is effected by the form material.

## Coil Design Facts and Formulae

It is unlikely that a coil could be precisely designed by mathematical calculation alone, but the factors and formula can give an approximation within a percent or two. The real value of the calculations is in giving a starting point for experimentation.

Given an adequate supply of wire, it is probably most practical to wind a number of coils with small differences in characteristics rather than to try and modify a coil between experiments.

A plastic tube with a slug of iron in one end and a slug of brass in the other is useful in evaluating a coil operating in its circuit. If inserting the iron slug in the coil improves performance inductance is too low and if inserting the brass slug improves performance inductance is too high. A practical "magic wand" for experimental work.

Factors and formulae for coils wound over core materials other than air are available from the manufacturers of the core materials. Examples given here are for air-core coils.

L = Self inductance in microhenrys.

N = Number of turns.

r = Radius in inches measured from the center of the form to the center of the coil body. (Not 1/2 of the inside diameter of the coil.)

1= Length of the coil in inches.

b= Depth of the coil in inches.

The self inductance of a single layer coil is found by dividing the square of the product of the number of turns and the radius by the sum of 9 times the radius plus 10 times the length.

A tedious and intimidating statement that is better expressed by the simple formula:

$$L = (rN)^2 / 9r+101$$

The formula is transposed to find the number of turns when the inductance is known:

$$N = \sqrt{L(9r+101)} \ / r$$

To find the inductance of a multi-layer coil, remembering that the radius is defined as above:

$$L = 0.8(rN)^2 / 6r+91+10b$$

Self inductance and mutual inductance in a multi-layer coil is a complex matter and this is why experimentation is required to arrive at the ultimate goal. It becomes necessary to begin with some assumed values to find a starting point and to then replace them with more appropriate values when you observe the results of initial calculations.

All of the useful formulae concerning inductance, capacitance, resonance, etc. are printed in compact electronics data handbooks. These will enable you to use the data you have to find the data you don't have so that you can design the coils you need and produce them on your universal winder.