RADIO & MODEL ENGINEERING

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Edited by ~ M.B. Sleeper

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Things We Have Learned in Our Shop

The experimental work done in connection with the working out of new equipment calls for methods applicable to the experimenter's workshop as well

THE majority of failures experienced by men who build their own radio equipment is due to mistakes and careless workmanship in small details, usually from lack of practice and familiarity with the fine points of craftsmanship.

tip end of the strip is to be under the wire but this is sufficient to hold up fairly in place until the winding is completed.

The larger part of the illustration shows one of the laboratory assistants soldering the taps, taken off in the manner just described, after the

Fig. 1. Showing a new and very satisfactory method of tapping coils.
Insert at left indicates position of copper strip.

The photographs reproduced here were taken around the laboratory which handles the work of getting out new designs and offer some suggestions which may help you in the things you are doing. Fig. 1 shows a new and very satisfactory method of tapping either single layer or bank wound coils. As the tapping point is approached the wire is scraped bare and a narrow strip of copper foil, about 0.005 in. thick slipped under the bare section. The winding is then continued after the strip has been pinned back out of the way. Only the

inductance for a C. W. transmitter was finished. The very least possible amount of soldering paste is used and only a tiny dot of solder. The soldering paste is particularly important for if too much is used it runs over the adjoining turns and makes an unsatisfactory and unsightly appearance. By rolling the outer end of the strip over a small brad a tube is formed in which the tapping wire can be inserted and soldered. This system is often times more satisfactory than the extra turn method for there is no possibility that, at the point where

the wire is twisted and brought off, as in the other method, a break will occur.

The left hand illustration in Fig. 2 offers a suggestion to those who have difficulty with excess soldering paste at the switch points. Here the switch point lugs, after being put in place are tinned and the paste wiped off with an old cloth and tooth brush. Later on, when the coil is mounted, there will be no necessity for applying any paste to the soldering lugs. Most brands of paste seem to offer excellent leakage paths across contacts. For this reason it is very important to have the joints clear and clean, as serious losses often occur when

Experimenters who wind their own variometers will be interested in the left hand illustration of Fig. 3. One of the greatest difficulties in making stator windings is to slip them off the form without damaging the coil. That trouble is over very nicely by the method shown. Six strips of paper binding taps are put on the form before the coil is wound. They are a little more than twice as long as the winding. Shortly after the coil is started the outer ends of the taps are moistened and bent over, and stuck to the wire. With the coil finished, the inside ends are also bent over and stuck down.
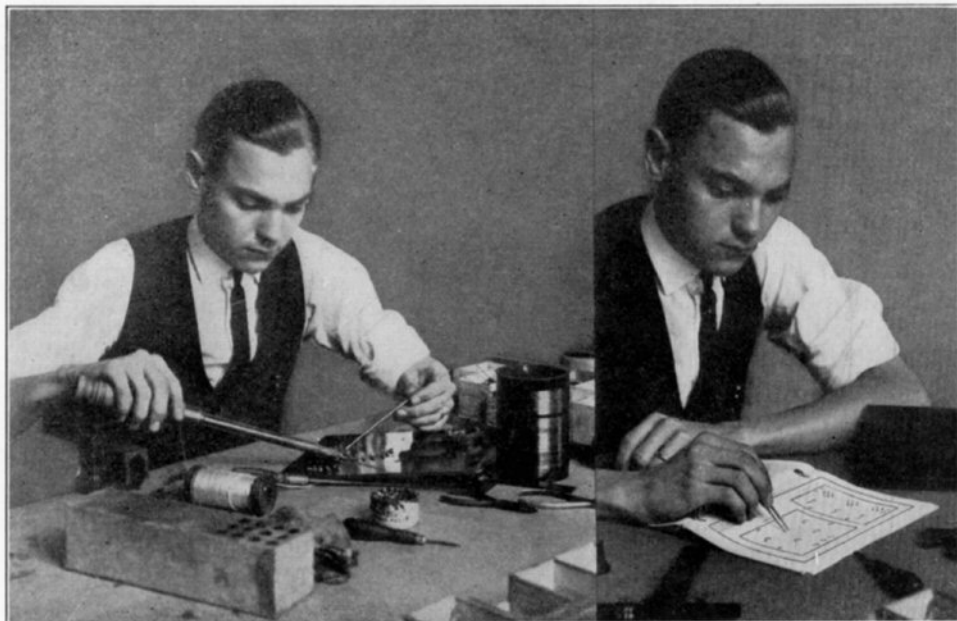

Fig. 2.   Left hand picture illustrates simplicity of soldering when lugs have been previously tinned. Above right shows method for taking off dimensions from scale drawings.

the resistance between the taps is not kept at maximum.

At the right in Fig. 2 the method for taking off dimensions to the panel is illustrated. The distance is first measured on the drawing by means of a pair of sharply pointed dividers. This measurement is then transferred to the panel and doubled. Next a scratch mark is run down the panel with a scriber and combination square. When the distance from the side is laid out on the panel and a line drawn at right angles to the first one the center for the hole is located. A center punch mark at the intersection helps to locate the drill accurately.

In this way a strong coil is formed independent of any varnish which may be applied later. Particularly when several coils are to be wound on the same form this system is advantageous because there is no varnish on the form to become sticky and impede the removal of the coil from the form. In addition the paper strips hold the turns closely together so that, when the winding is inserted in the stator, if a part of the coil is not held firmly, there is more support than the mere binding of varnish. Moreover, varnish or shellac stick to the paper much better than they do to the wire itself. A completed stator winding can be seen on the bed of the lathe in the right hand picture.

Like so many of the variometer stator winding forms, our first one was slightly loose. Accordingly, strips of glued paper tape were stuck to the ball, strip on strip, until the coil was enlarged sufficiently to make a perfect fit in the stator or stationary forms. In addition, the friction was reduced to such an extent that no trouble was experienced in slipping the coil off the winding form. This method of shimming worked out exceedingly well.

To check the number of turns in each stator coil a Veeder counter was used. The shaft was driven into a wooden plug, and the plug fitted in a hole in the center of the wooden form. You can see, in the illustration, a block of lead melted into the base of the counter to keep it

of the rotor. A similar disc is held in place by pressure of the tailstock of the lathe. Attached to the disc carried in the chuck is a brass strip pressing against the shaft of the rotor like a lathe dog. This carries the moulded form around during the winding in a most satisfactory manner. The holes are drilled at the outside and on each side of the center section to take the ends of the windings in accordance with customary practice. When one side of the rotor has been wound it is removed and turned around. But the left is rotated in the same direction. As a result, when the inside ends of the coils are joined the direction of the winding is the same as if it were a straight coil.

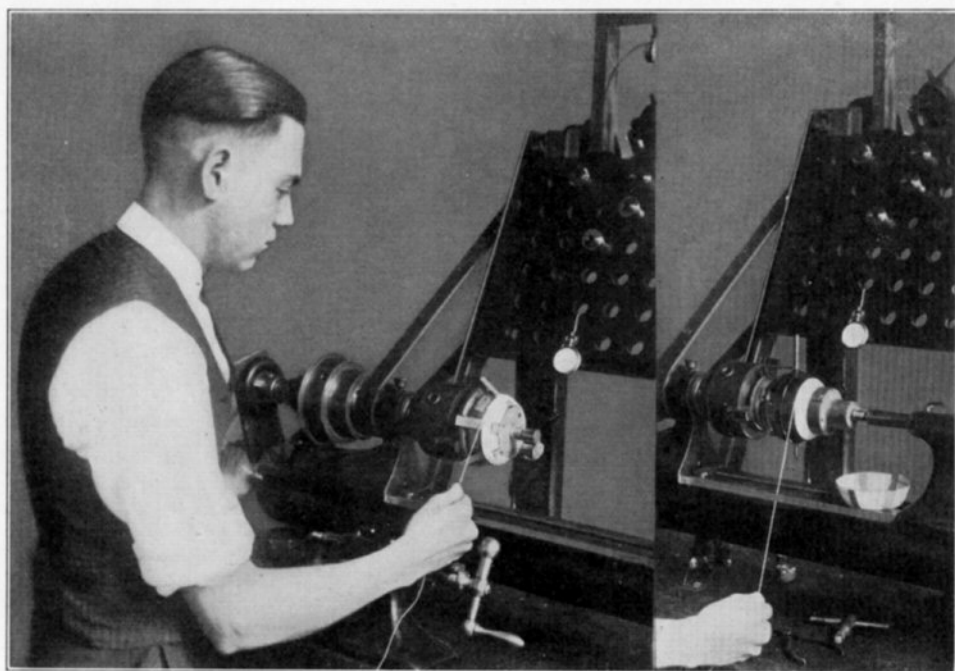Slight mechanical imperfections often result

Fig. 3. Laboratory method of winding stators. A simple hand coil winding machine will serve the experimenter equally well.

from revolving as the shaft rotates. No reset is needed. Each time a coil is wound the winder is rotated until an even 50 shows, and the number of turns counted from that.

The rotors used for Sleeper standardized moulded variometers, unlike other types, are split at right angles to the shaft. This introduces something of a problem in winding as the two halves are only held together by small locating pins or holes in the very narrow thickness of the walls and the binding effect of the wire. A little jig to hold the rotor is illustrated above. A wooden disc is recessed at a diameter just great enough to slip over the rim

in failure to obtain maximum efficiency with a set even when extreme care is exercised in following detailed wiring diagrams. Before building a piece of apparatus it is strongly recommended that tests be made on the individual parts which make up the instrument. Frequently a variable condenser is shorted due to a bent plate—A simple test can be made by means of a dry cell and a buzzer wired in series. One lead is fastened to the rotary plates while the other is similarly connected to the stationary plates. If in rotating the plates the circuit is completed the condenser is faulty and should be replaced to avoid a possibility of rewiring.

A Variometer of High Efficiency

Some interesting notes and data on variometer construction and operation.

VERY rapidly the wooden variometer is being replaced by types employing molded stator and rotor frames. The latter are more attractive in appearance and more permanent in construction than the wooden types which frequently shrink and warp, causing the windings to move out of place. Moreover, the practical limitations of manufacturing the wooden parts necessitate a large clearance between the two windings. As a result the amount of variation in inductance between the minimum and maximum settings is comparatively small.

work of mechanical strain the mounting block was made very close so that any tendency to break off is distributed around the strong center framework. At each end holes are molded into the shaft bearing to carry the contacts. The nickel plated strips at the front and rear act as terminals from the shaft.

Unlike other variometers the ball is split at right angles to the shaft and the shaft molded into each half. In this way there is no possibility for the shaft to come loose or to run out of true. Small lugs and holes in each half of the ball locate the halves in position. The
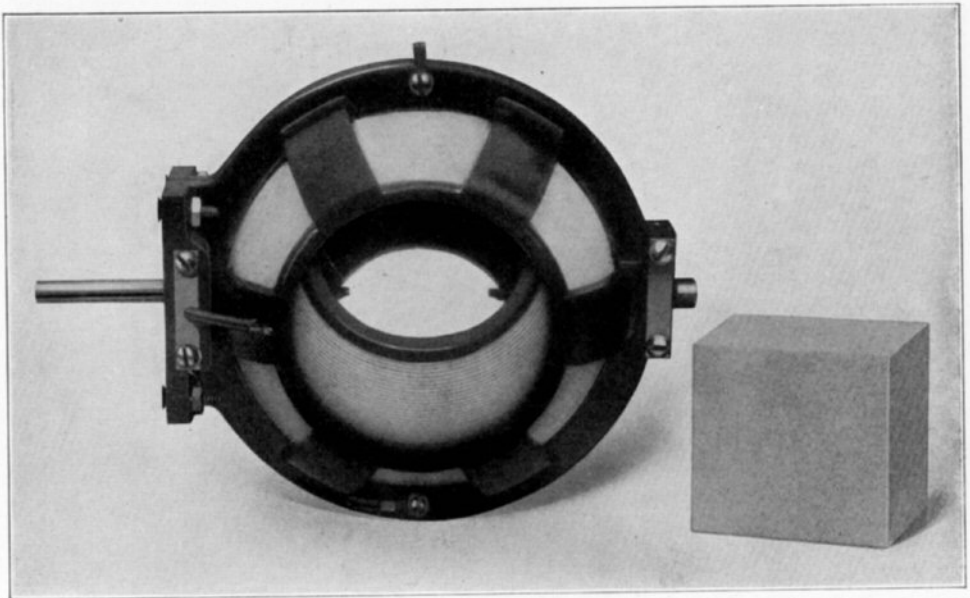

Fig. 1.   The completed variometer.   Cube at right 2 inches on a side, weighing 10 oz. shows amount of molded material used.

Molded variometers have, however, the disadvantages of high losses due to the presence of molded material within the fields of the coils. The variometer illustrated in Figs. 1 and 2 was planned to show an efficiency even greater than that of wooden variometers by cutting down the volume of condensite to an absolute minimum. At the same time it was necessary, of course, to maintain a margin of mechanical safety. Fig. 2 shows the separate stator and rotor parts before assembly. The stator is in the form of a cage carrying at one end one-half of the mounting block. To relieve the frame

binding of the wire holds the parts tightly. Small shoulders at the outside of each half around the shaft act as bearings against similar shoulders on the inside of the stator. Thus the end play is taken up. Constructing the ball in this manner it is possible to use an extremely thin wall, only $\frac{3}{32}$ in. thick except for shoulders around the shaft on the inside which act as extra support. The perfection of detail is indicated by the construction of the shaft at the inside where the coil lead is soldered on. The shaft is turned down to $\frac{1}{16}$ in. diameter. This is done so that, in soldering on the lead,
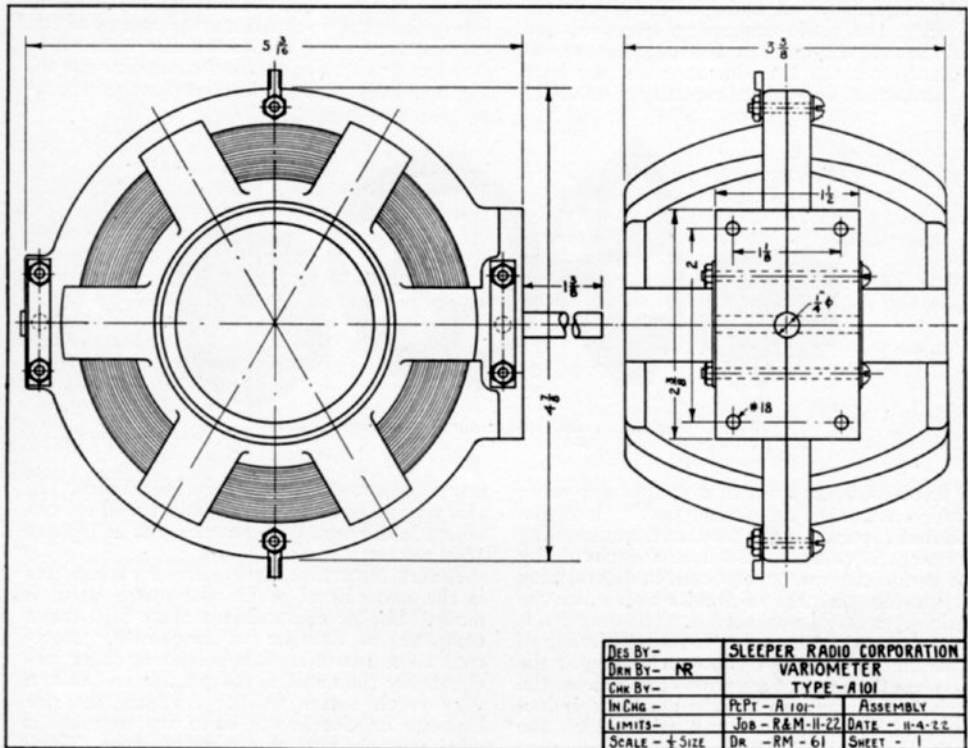
Fig. 3. Outline of drawing of variometer showing location of mounting screws.

an excessive amount of heat will not be transmitted to the entire shaft, causing it to become loose where it passes through the molded ball. Ordinarily stator windings are merely held together by the binding action of a heavy coat of varnish. This method was not approved because it frequently happens that the coil is secured to the frame at the inside but is loose at the outer part. Then the entire strain of holding the free turns comes upon the varnish binder. Coils for this variometer are wound over six narrow strips of gummed tape. When the winding is completed the ends of the tape are bent over on the outside of the winding, thus making a strong coil even tho no varnish is used at all. These strips are hidden beneath the six arms of the frame work so that they do not detract from the appearance of the instrument.

Fig. 3 gives an outline drawing of the variometer and the location of the mounting screws from which any additional dimensions can be scaled since the drawing is one half size.

The Electrical Testing Laboratories of New York City have provided some rather interesting information on this variometer in their report number 40849.

Some of the data is given below.

1. Direct Current Resistance.
   D. C. Resistance, ohms—1.25

2. Inductance in millihenries.

Setting	audio frequency	radio frequency
5	—	0.08
10	0.10	0.11
15	0.12	—
20	0.15	0.20
40	0.31	0.42
60	0.55	0.77
80	0.74	0.99
95	0.84	1.14

3. Distributed Capacity.

Setting	Microfarads
10	0.000036
20	0.000026
40	0.000020
60	0.000017
80	0.000014
95	0.000012

The two important factors are the inductance ratio and distributed capacity. Upon the inductance ratio depends the wavelength range

which can be covered, and upon the distributed capacity the radio frequency losses in the variometer. From 0 to 100 degrees the inductance ratio is 1 to 24, an unusually high ratio while the distributed capacity of 0.000012

circuit. That is the wavelength is increased from minimum to maximum by means of the variometer. Then the variometer inductance is reduced to zero and a fixed condenser cut in. The wavelength is again increased as the variom-
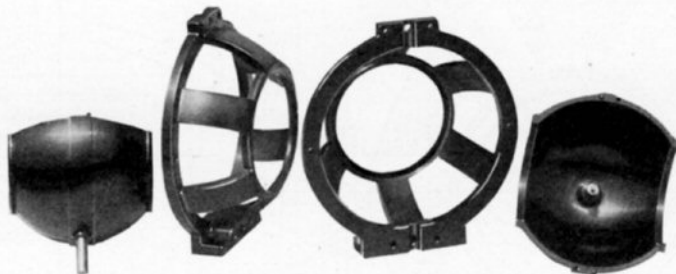

Fig. 2.   Separate stator and rotor parts before assembly.

to 0.000036 is far lower than that of any other variometer. One advantage in the low distributed capacity is the fact that, in designing circuits, the capacity added to the circuit by the variometer can be neglected in determining the wavelength range of circuits with which the variometer may be connected. The question is often asked, "what is the wavelength range of a variometer"? There is no such thing as the wavelength range of a variometer because the variation depends so largely upon the inductance of the secondary coil with which the variometer is used. Some companies employ small mica condensers connected across the grid and filament of the detector tube to increase the wavelength range of the secondary

eter is adjusted to maximum inductance. In this way an ordinary variometer tuned set can be made to respond to wavelengths as high as 1500 meters.

A very important feature about variometers is the material of which the frame work is made. Shellac compositions cause high losses compared to Bakelite or Condensite. Moreover these two materials are far stronger mechanically than shellac compounds and take a very much better finish. An easy test for Bakelite or Condensite is to try to make a mark with the part on a piece of paper. These materials will not leave any mark on the paper while shellac or other substitute compounds make a black line.

Note.   The high efficiency variometer described in the foregoing article, completely assembled, may be secured from any of our distributors.   Price $7.50

101 Receiving Circuits
Eighth Installment
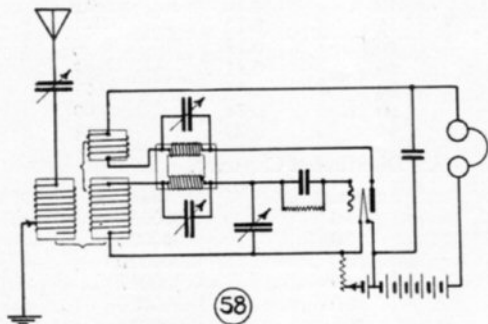
58. A combination of high and low frequency regeneration is illustrated in this diagram. The customary tickler coil is coupled
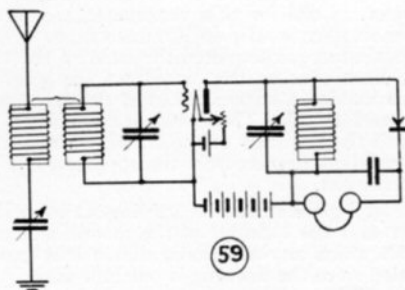
to the secondary of the tuner for radio frequency feed-back, while the primary of an iron coil transformer in the plate circuit and the

secondary in the grid circuit provide for regeneration at audio frequencies. Condensers are shunted across the windings of the iron coil transformer as by-passes for the radio frequency currents. They are variable to permit adjustment of the degree of audio frequency feed-back. In practice this system gives exceptionally good amplification for a single tube outfit, but some difficulty is experienced in keeping it in stable operation. For this reason, regenerative amplification at two frequencies with a single tube is seldom used.

59. While this diagram shows a circuit employing a vacuum tube, a crystal is used as the detector. The audion has no grid condenser and is used to amplify the radio frequency energy it receives from the tuner. An inductance shunted by a variable condenser is placed in the plate circuit of the tube. In this oscillatory circuit, the incoming signals are reproduced with an increased amplitude, owing to the amplifying properties of the vacuum tube. Since the current has an inaudible frequency of variation, it is necessary to employ a detector before the signals may be heard. This system of employing a crystal detector amplifier is a popular circuit in England, but is not used very extensively in America.
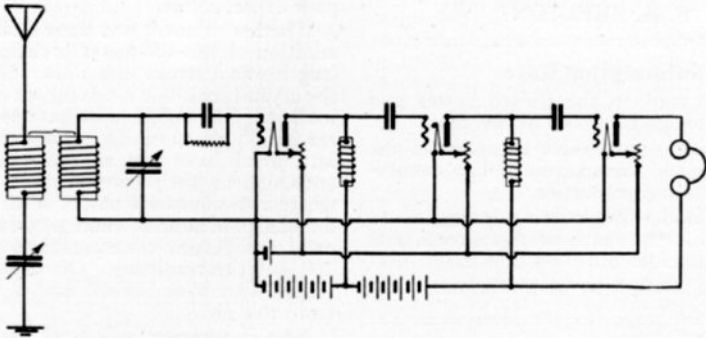
65. An impedance coupled two-stage audio frequency amplifier is shown wired to a two-circuit tuner in this hook-up. In place of the transformers used in the preceding amplifiers choke coils and condensers are employed. The impedances are connected from the B battery to the plates so that the necessary charges may be placed upon the anodes without providing paths for audio frequency currents to the filament. These, being stopped by the choke coil, are carried to the grid of the following tube thru a fixed condenser which prevents the plate battery from giving the grid a high positive charge.
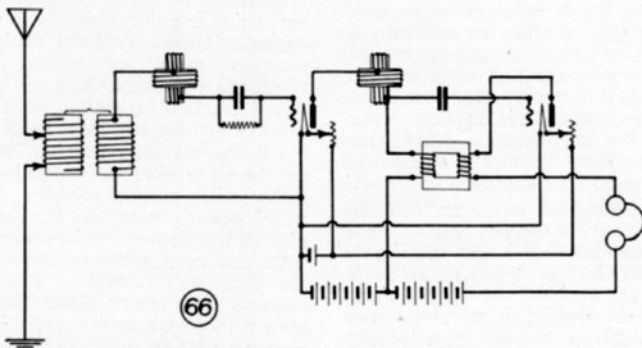
66. The regenerative feature is added to this impedance coupled amplifier by placing a variometer between the detector plate and the primary of the amplifying transformer. Feed-back is obtained in the amplifier tube by coupling the plate circuit to the impedance coil. In this way we get radio frequency regeneration in the first tube and audio frequency regeneration in the second. When properly adjusted this makes an efficient two-tube outfit.

RADIO AND MODEL ENGINEERING

Subscription Rates

EDITORIAL

TWO things have happened this fall which, tho they may not be appreciated immediately by radio Experimenters, are helping tremendously to advance the art. One is the lateness of fall business. The other is the use of 360 and 400 meters for broadcast transmission.

To those who are not intimately concerned with the details of the industry, a review of the radio situation may be interesting. Following the start of the summer season, which has been always very quiet, manufacturers generally maintained their production schedules so that they would be prepared to meet the big demand expected with the first of September. Sales during June, July, and August were small, cancellations large, and collections poor. Newcomers having few accounts receivable, and those not collectible, promptly succumbed under pressure of current expenses.

Others, a little stronger, held out until September. But the orders did not come. Their goods, of cheap and inferior design, lacking the support of advertising, were not at all in demand. Moreover, dealers' shelves were still groaning under the weight of worthless merchandise held over from last spring, when anything could be sold. October arrived, and still no widespread revival in orders. One by one those companies have collapsed, the little "down cellar factories," the imitation machine shops, and the big stock selling fakers. They couldn't stand the gaff.

At the same time, the dealers have learned what kind of apparatus sells and stays sold, what manufacturers stand behind their goods with guarantees that offer real protection to them and to their customers—and it has been a very expensive lesson.

Altho you may not know it, you and the manufacturers who are powers in the industry have been drawn closer together, for you have been opening their eyes about their products and they are working to make those products more nearly according to your ideas.

When, this spring, you look back a year, you will find radio merchandise and merchandising methods utterly changed and improved beyond your expectations.

Whether or not it was done deliberately, the addition of the 400-meter broadcasting wavelength was a stroke of genius. No longer has the crystal junk-box receiving set a place in the market. The public must have sets capable of reasonably sharp tuning. Those cheap crystal sets, which have been sold in countless thousands, defeat their own purpose in localities where two waves are used. With the demand for sharp broadcast tuning comes automatically a relief from the complaints made against 200-meter transmitters. One almost feels that K. B. Warner or Schnell had a finger in the two-wave pie.

Now if someone will work out that wave analyzer so that receiving sets can be rated for sharpness of tuning, interference problems can be put up, largely, to the lack of judgment on the part of the person buying a receiving set of broad tuning characteristics.

The super-heterodyne system, after exciting passing notice last year, seems to have been dropped. That is due for a decided revival this winter, however. In preparation for an article in R and M, showing features not fully appreciated by Experimenters, some surprising results have been obtained. As a matter of fact, the possibilities are greater than of radio frequency amplification, the circuits in general easier to handle, and the equipment in every way more satisfactory to use. More tubes are required, to be sure, than in the reflex circuits now attracting attention, but the adjustments are more stable and more readily made.

Anyone who suggests that interest in radio is on the wane discloses a decided lack of familiarity with current events. An experiment which opens a new field for the use of radio is that of the Pennsylvania Railroad in receiving broadcasting stations on an outfit installed in the Broadway Limited. The success of the venture leads one to expect that very soon the men who do not care to join in the smoking-compartment arguments and the ladies who are tired of reading can ask the porter for a pair of Pullman phones, plug them into a concealed jack, and listen in to the broadcasting stations.

M. B. SLEEPER,
Editor.

Undamped Wave Transmitter

Altho this outfit is designed for telegraph transmission up to 25 miles it can be easily modified for telephony with a wavelength range of 10 miles.

Vacuum Tube Transmitters OF the many suggestions and recommendations which have been sent in for a vacuum tube transmitter the chief demand seems to be for an outfit that can be constructed of parts readily available and one which will not require too much auxiliary equipment. The set described here calls for practically no special parts, uses UV201 or Western Electric VT1 tubes, can be operated on 90 to 150 volts of B batteries with

that, with varying types of antennas the set can be tuned down to 200 meters. As a matter of fact the lower wavelength on which transmission is accomplished the greater the efficiency down to the point where the natural period of the antenna is approached.

The transmitting range of 25 miles for telegraphy or 10 miles for telephony is a conservative estimate. Many experimenters find that they can increase the transmitting range of a low power outfit by employing Western Elec-
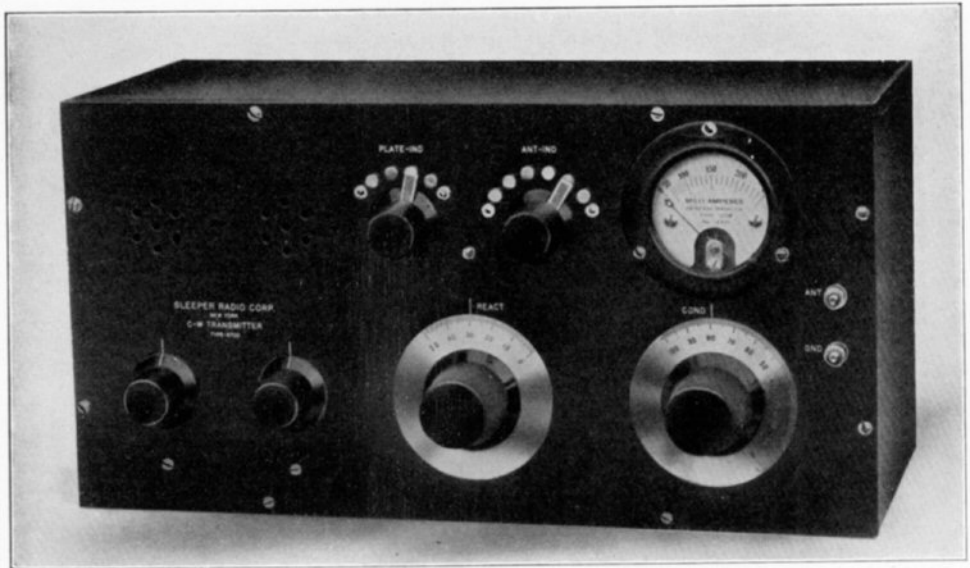
Fig. 2. Front view of completed instrument. Note simplicity of design.

the ordinary 6-volt storage batteries for the filament. Arranging the set in this way it is not necessary to employ a high voltage generator or the extra voltage needed to operate UV202 tubes. Tests were made with UV202 tubes with 6 volts on the filaments and 150 volts on the plates but no improvement was accomplished in the radiation.

Undamped wave telegraph transmitters are exceedingly efficient in operation for surprising results can be obtained with very low power. Moreover an experimenter is only safe from complaints against the interference he causes to the operators of broadcast receiving sets when he uses this type of transmitter. Sufficient variation in the controls is allowed so

tric VT1 tubes altho that type is primarily designed for receiving. By cutting a special slot in the socket tube VT2 tubes can be employed, giving a still greater transmitting range.

General Description of the Set The circuit for this set calls for an antenna inductance which is also connected in the plate circuit, a grid coupling coil, plate condenser, two tubes in parallel and a radiation meter. The absence of fixed condensers, special resistances and choke coils makes the outfit easy to construct, low in price, and sure in operation.

On the front of the panel are the radiation meter reading from zero to 250 miliamperes of

the General Radio type, switches for the adjustment of the inductance in the plate and antenna circuits, and controls for the condenser, grid coupling and rheostats. A base panel measuring 5 by 5 ins., $\frac{3}{16}$ in. thick, carries the tube sockets and binding posts for the key, B battery, and A battery. Leads are introduced through holes in the rear of the cabinet.

The variocoupler is made up of a ball carried on a shaft which passes through a long bushing secured to the panel and independent of the tube on which the tuning inductance is wound. This arrangement was decided upon because it is difficult to drill accurately the holes in the tubing to act as bearings to the shaft.

Drilling the Panels   Fig. 5 gives a one fourth scale drawing of the front and base panels. Dimensions can be taken off and transferred to the panels by means of dividers, multiplying each

sandpaper. Remember when doing this to take straight strokes clear across the panel for otherwise irregular cross scratches will appear.

The Inductance   Fig. 5 illustrates at one fourth scale the location of the taps. An L. P. F. tube $3\frac{1}{2}$ ins. in diameter and $2\frac{1}{2}$ ins. long with a $\frac{1}{8}$ in. wall carries the stationary coil. The winding is of No. 20 D. C. C. wire, B & S gauge, (No. 18 S. W. G.). Taps are taken off at the 24, 26, 28, 30, 32, and 36 turns. Taps from the 28th, 30th, 32nd and 36th turns are connected to both antenna and plate inductance switches. Holes for the screws to fasten the tube to the mounting pillars are located 3-16 in. in from the end of the tube.

Just beneath the lower coil mounting pillar is a hole 13-32 in. in diameter through which the bushing for the rotor shaft is inserted. An L. P. F. piece measuring 1 in. by $\frac{3}{4}$ in. thick, is slipped over the bushing and both bushing
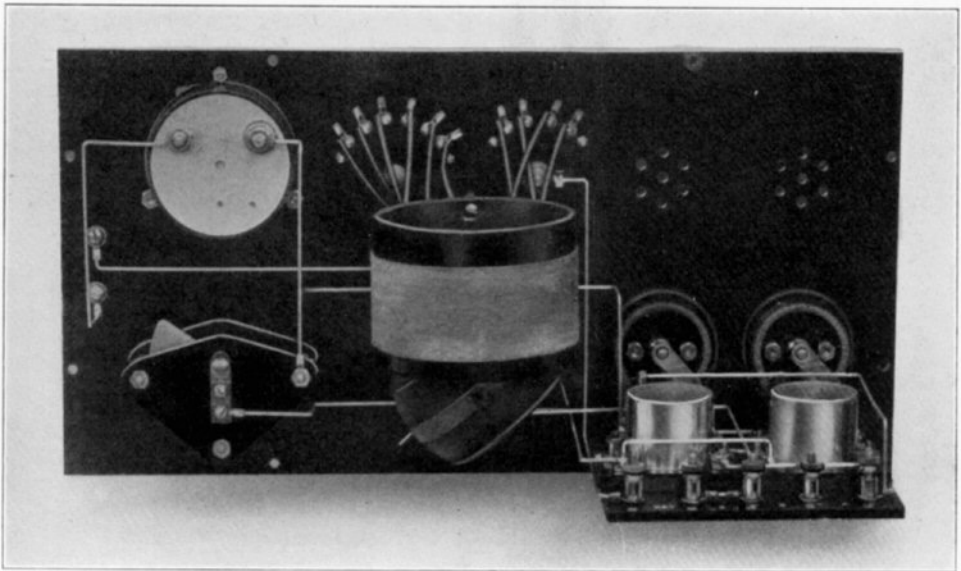
Fig. 2.   Rear view of transmitter removed from cabinet.

distance thus found by four. Drill sizes are indicated on the drawings. Two concentric circles show that the hole is countersunk for flat head screws. If L. P. F. panels are used the work of locating the holes is simple since the edges are smoothly cut and the corners perfectly true.

Those who prefer a polished finish on the panels should rub them down with a soft cloth and oil, cleaning the surfaces thoroughly so that no oil will be left to hold dust. On the other hand a dull finish can be obtained by rubbing the panel with linseed oil and No. 00

and terminal block are clamped by a nut screwed down over the threaded part of the bushing. Two flat head screws in the terminal block carry lugs which provide connections for the flexible leads from the ball and the external wiring.

The ball, 3 ins. in diameter, is wound with approximately 30 turns, on each side, of No. 24 S. S. C. wire, B & S gauge, (No. 22 S. W. G.). Both leads from the rotor winding are brought out through a hole at the side of the ball which is away from the stationary coil. The stopping pin in the ball prevents it from rotating
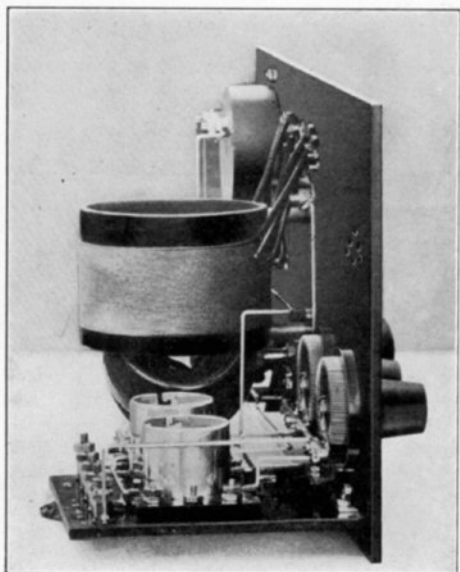
Fig. 3. Side View of Transmitter.

more than 180 degrees. It is important when winding the rotor to make sure that the turns are put on in such a direction that they form a continuous winding. That is, the two halves, when the adjacent center leads are connected together should be wound in the same direction.

All the individual parts should be made ready before any assembly work is started.

Instructions for Assembly

1. Fasten the two binding posts, with the round head screws, to the panel as shown in the diagram by numbers 26 and 37; placing a terminal lug between each screwhead and washer. The posts are to be on the front or engraved side of the panel, while the lugs, shown by the short heavy lines, are on the back, and should point in the directions indicated in the layout.

2. Into the four end holes of the groups of switch holes under the words PLATE-IND and ANT-IND, place the four switch stopping points. Hold these in place with the hex nuts furnished.

3. The remaining holes referred to above, are filled with the switch contact points, placing the heads against the front of the panel, and the lugs and nuts on the rear as shown. Tighten the nuts to avoid loose connections.

Note:—Put a little solder on the ends of each lug, before fastening in place. Remove surplus paste on the lugs with an old tooth brush or cloth.

4. Mount the two switches and tighten rear collars on shafts, making sure that a firm pressure is obtained between the switch-arms and contact points.

5. Mount the variable condenser and the two rheostats thru the screws and nuts furnished.

6. Place the contact arms of the rheostats thru the holes provided for them, and shift the arms so as to have them in the "OFF" position, or resting on the bare elements of the rheostat
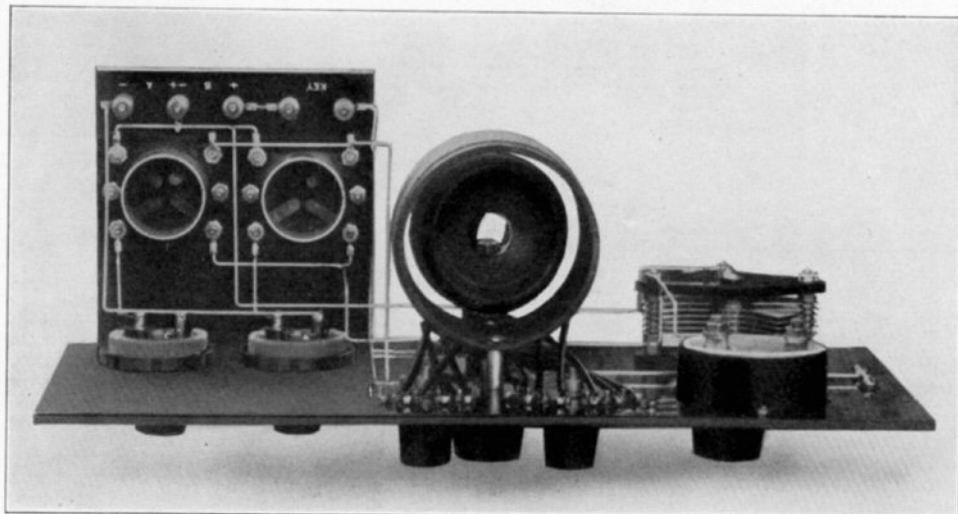
Fig. 4. Top view of instrument illustrating wiring.

winding. This is clearly shown in the drawing. Now, fasten the knobs on the shafts of the contact arms, observing that the white lines of the panel and knob coincide, and making sure that a firm pressure exists between the contact arms and the resistance windings.

9. Fasten the angle brackets to the base panel, with two $\frac{3}{8}$ in. $\frac{6}{32}$ F. H. machine screws and nuts, and mount it on this panel to the front panel with two $\frac{3}{8}$ in. $\frac{6}{32}$ R. H. machine screws and nuts.

10. Put the bushing of the variocoupler
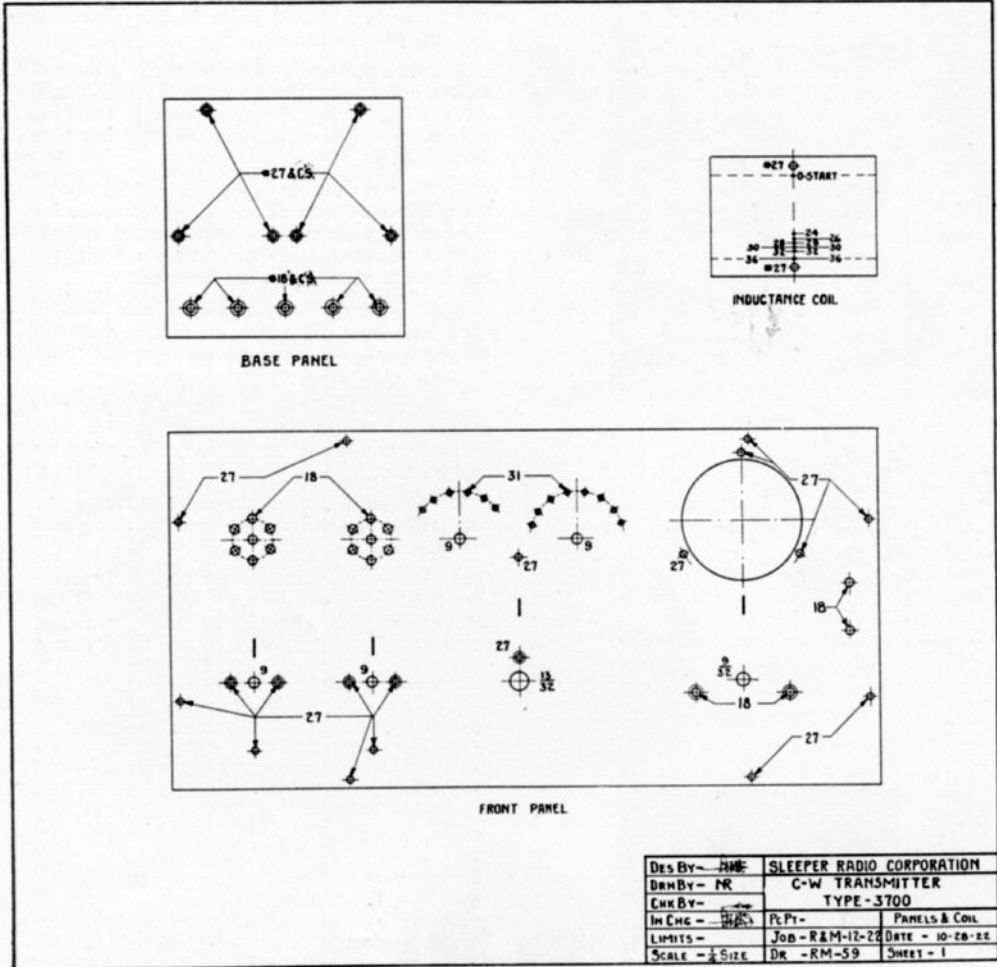
Fig. 5.   Scale drawing of front and base panels.

7. Take the base panel (5 by 5 by $\frac{3}{16}$ L. P. F.) and fasten the remaining five binding posts at 11, 12, 14, 15, and 23.

8. Next mount the two sockets on this panel holding them down with four $\frac{3}{4}$ in. $\frac{6}{32}$ F. H. machine screws and nuts. It is important to have the relative positions of the slots of the socket as depicted in the diagram. Failure to observe this may mean the burning out of the vacuum tubes.

rotor thru the $\frac{13}{16}$ in. hole in the middle of the panel, with the flange against the front. Slip the small 1 in. by $\frac{7}{8}$ by $\frac{3}{16}$ in. block over the bushing as shown by the dotted lines in the diagram. Fasten the bushing and block with the nut supplied.

11. Connect 1 to 2. To do that, first fit a piece of square tinned wire from 1 to 2, running it as directly as possible with right angle bends, avoiding contact with any intermediate metal

or wire. Then solder the terminals neatly. For all other connections, similar fitting and soldering processes are used.

12. In the order mentioned connect 3 to 4, 5 to 6, 7 to 8, 9 to 10 to 11, 12 to 13, 14 to 15, 16 to 17, 18 to 19, 20 to 21, 11 to 16. There will be two leads soldered to lug numbered 16. Connect 23 to 24, 25 to 26.

13. Take some of the wire which was used for winding the inductance coil, cut off eleven 4 in. lengths and solder them to the copper foil strips as shown in the diagram. Note that the four upper taps have two leads, and the remaining three have single leads.

14. Slip the variocoupler rotor ball thru the bushing. Solder the two flexible leads to lugs numbered 20 and 22, in the diagram.

15. Mount the inductance coil in place, holding it with a ⅜ in. F. H. machine screw at the bottom, and a ⅜ in. R. H. machine screw at the top.

16. Fasten the dial and knob on the rotor shaft, so as to have the 50 line of the dial scale coincide with the engraved line on the panel, when the rotor is in the position depicted.

17. Run the two leads from the uppermost top of the coil to lugs numbered 27 and 33. Cut off a piece of empire tubing long enough to cover leads from tap to lugs. Slip the tubing over the leads, scrape off insulation and clean the wire beyond the tubing, and solder to lugs mentioned. Clip the surplus wires extending beyond the lugs.

18. Repeat this operation for the second, third and fourth taps from the top.

19. From the fifth and sixth taps, the single leads is brought to lugs 31 and 32 respectively.

20. Fasten the hot wire ammeter to the panel with three ⅜ in. $\frac{6}{32}$ machine screws and nuts.

21. Connect 37 to 38, 39 to 40.

22. Run a wire from some suitable point 41 on the connecting wire 39 to 40, to lug marked 1.

23. Solder the lead from the lower end of the inductance coil to 42, which is on the wire running from 41 to 1.

24. Mount the 0-100 dial and knob on the variable condenser shaft so as to have the 100 line of the dial and the white line on the panel coincide, when the rotary plates are wholly interleaved with the stationary plates.

Operating and Testing With the set completely assembled and mounted in the cabinet connections should be made to the antenna and ground posts, B batteries of 90 to 150 volts to the post marked for the purpose, a 6-volt storage battery to the proper terminals and a telegraph key around the posts indicated. Light the filaments to full brilliancy and press the key. If no radiation is indicated by the hot wire ammeter the grid coupling ball should be rotated until the pointer moves. Then each control should be gone over carefully until maximum radiation is obtained. To measure the wavelength in an ordinary wavemeter couple the meter to the transmitter inductance and watch the radiation ammeter for a setting of the wavemeter which causes a slight movement of the ammeter. This is caused by the absorption of energy in the wavemeter when the two circuits are at resonance. It will be found that greatest radiation is ordinarily obtained when a minimum amount of plate capacity is employed.

A short antenna, approximately 75 feet long made up of three or four wires spaced 2 feet apart will give greater transmission than a single wire such as is used for receiving. Height is also important in an antenna used for sending. At the same time it must be remembered that the wires must not be so high that a long leading is made necessary.

If you want to use the set for telephony insert a switch in place of the key, wind three or four turns of annunciator wire around the antenna inductance and connect the ends of that coil to a telephone transmitter. Speaking into the microphone changes the resistance of the 4-turn circuit, absorbing varying amounts of energy from the transmitter. This system is called absorption modulation. With different transmitters it may be advisable to vary the number of turns around the antenna coil. The switch is not necessary but is suggested so that you will not have to hold down the key during transmission.

Like all other radio equipment this set may develop some difficulties altho the simplicity of the circuit minimizes the opportunity for failures. If the ammeter does not indicate any radiation find out if the ammeter has either an open or a short circuit. This may be done by means of a pair of telephone receivers in series with a dry cell. Be very careful not to apply the dry battery current directly to the ammeter as it will burn it out. A short circuit in the plate condenser or open circuits in the windings or connections may be responsible for the failure of the set to oscillate properly. Sometimes the contact pins on a vacuum tube do not make perfect connection with the socket springs. It sometimes happens, too, that the tubes themselves are defective. You must also check up the polarity of the batteries and make sure that both A and B batteries are up to their full voltage. When maximum power is needed the filament of UV201 tubes must be burned at full brilliancy, that is, working on a 6-volt storage battery with the rheostats entirely cut out.

We should be very much interested to hear reports from experimenters who build this transmitter as to the distance they are able to cover.
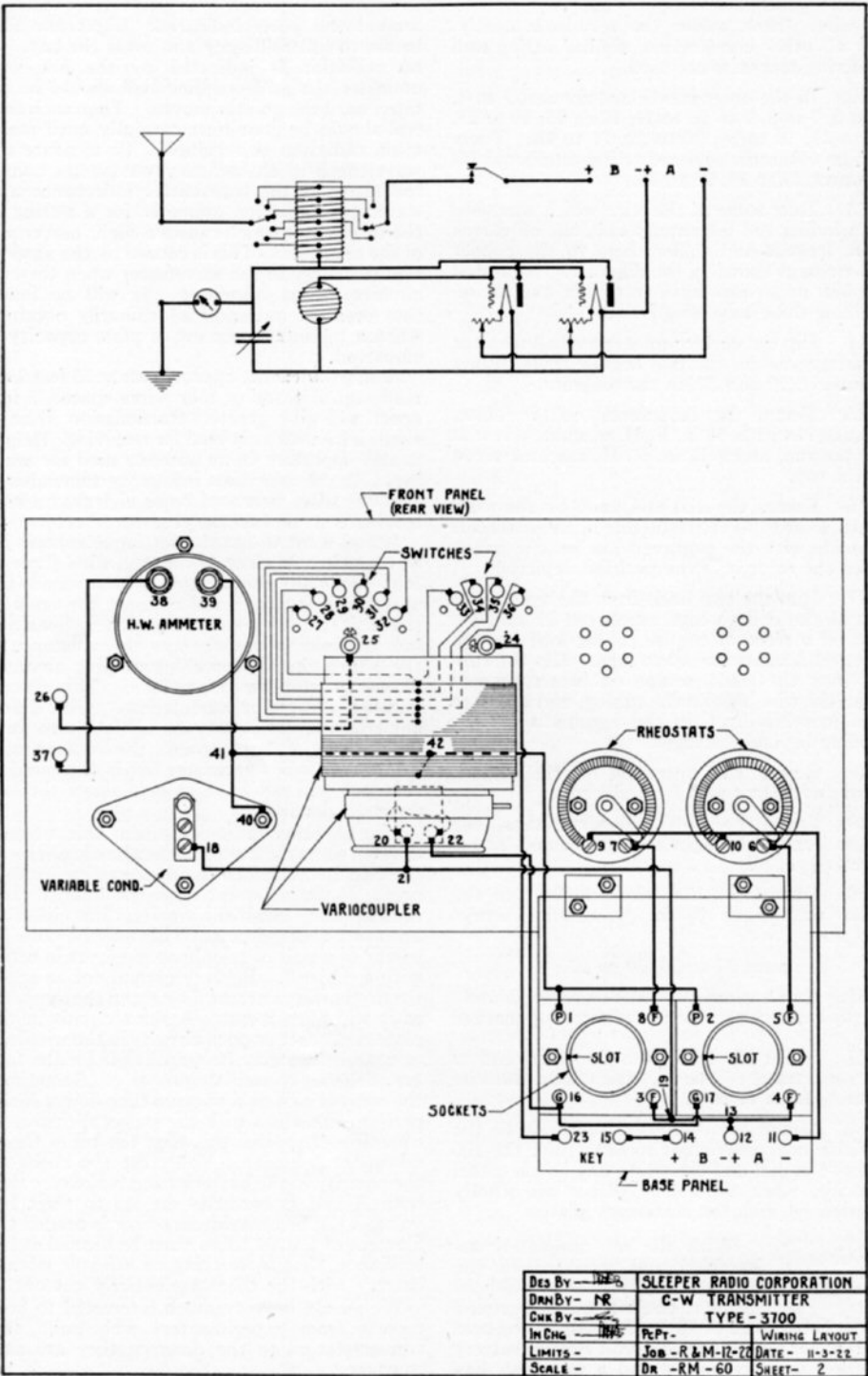
Fig. 6.   Schematic and picture circuits for the transmitter.

Inductance Tables

Tables for the determination of the inductance and dimensions of coils from 3 to 10 inches in diameter and 0.1 to 10 inches in length.

Use of Inductance Tables

THE purpose of these Inductance Tables is to overcome one of the greatest obstacles that has tormented experimenters in their attempts to design accurate receiving circuits and vacuum tube transmitting circuits. The practical impossibility of determining the inductance of coils without resorting to intricate formulas too difficult for shop application, or applicable only to coils already wound, has been the stumbling block of the most conscientious and careful.

Now, however, through use of the Inductance Tables published in this pamphlet, any given inductance, or any given factor affecting inductance can be determined with almost absolute accuracy. By simple multiplication or division, inductance, diameter, turns per inch, or length required for any given conditions can be found.

The experimenter or commercial designer can use these Inductance Tables with complete confidence in the results obtained. Values will be found to be as exact as the experimenter's own hand work. With even a fair standard of work, coils wound from the figures given in the tables will not vary more than 3% from the true values.

Inductance of Single Layer Solenoids

The man who is designing coils may have any one of several lines of attack. He may want to know the inductance of a given coil, or the length, or diameter, or size of wire to produce a certain inductance. Methods of solution are given below:

1. To find the inductance, in cms., of a coil of given length, diameter, and turns per inch:

a. Under the column headed by the given diameter, run down to the value opposite the given length. Multiply this value by the turns per inch squared. The result is the inductance, in cms., of the coil.

b. Example. A coil 4 ins. long is wound for 8.5 ins. with wire giving 50 turns per inch. The value in the "4 In." column, opposite "8.5 Ins." is 2819. This multiplied by 50² gives

2819 x 2500 = 7,047,500 cms.

2. To find the diameter of a coil to produce a certain inductance, given the length and turns per inch:

a. Divide the inductance, in cms., by the turns per inch squared, and locate the column in which this value appears opposite the given length. The heading of that column is the required diameter.

b. Example. 5,100,000 cms. inductance are required of a coil 6 ins. long, wound with 40 turns per inch. The inductance, divided by the turns per inch squared is
5,100,000 ÷ 1600 = 3,190
The nearest value opposite "6 Ins." is 3211, in the column headed "5.50 Ins.," which is the diameter required.

3. To find the length of a coil to produce a certain inductance, given the diameter and turns per inch:

a. Divide the inductance, in cms., by the turns per inch squared, and, in the columns headed by the given diameter, locate the value found. The figure at the side shows the required length.

b. Example. 1,500,000 cms., inductance are required of a coil 3.75 ins. in diameter, wound with 60 turns per inch. The inductance divided by the turns per inch squared is
1,500,000 ÷ 3,600 = 417
The nearest value in the "3.75 Ins." column is 407.7, opposite "2.1 Ins." which is the length required.

4. To find the turns per inch to produce a certain inductance, given the length and diameter:

a. Find the value under the diameter column opposite the proper length. Divide the inductance, in cms., by the value found, and take the square root of that answer. This gives the required turns per inch.

b. Example. 7,100,000 cms., inductance are required of a coil 5.5 ins. in diameter and 9.6 ins. long. The value in the "5.5 ins." column, opposite "9.6 ins.," is 5799. The inductance, in cms., divided by the value found, is
7,100,000 ÷ 5,799 = 1,224
The square root of 1,224 is 35, which is the turns per inch required.

Inductance of Bank-Wound Solenoids

Banked windings can be treated, with very little error, as single-layer coils, counting the total of turns per inch as the turns per inch of a single-layer coil.

That is, a coil may be wound in three banks with wire giving 40 turns per inch. The turns per inch would be taken as

40 x 3 = 120 turns per inch.

The value obtained would then be used in the processes just described.

Example. 10,800,000 cms. inductance are required of a coil wound in three banks with

wire giving 30 turns per inch, on a tube 4.5 ins. in diameter. To find the length necessary:

Three banks, each of 30 turns per inch, gives 90 turns per inch. The inductance divided by the turns per inch squared is

$$10,800,000 \div 8,100 = 1,333.$$

The nearest value in the "4.5 Ins." diameter column is 1334, opposite the "4.0 Ins." length. This is the length required.

Inductance of Figure 8 Coils

Figure 8 coils should be treated as single-layer solenoids, the inductance of which is qualified by the multiplier given in the table below.

$\frac{L}{D}$	κ	$\frac{L}{D}$	κ
0.02		0.30	1.465
to		0.31	1.450
0.22	1.550	0.32	1.435
0.23	1.545	0.33	1.420
0.24	1.540	0.34	1.400
0.25	1.530	0.35	1.383
0.26	1.520	0.36	1.366
0.27	1.510	0.37	1.348
0.28	1.495	0.38	1.330
0.29	1.480	0.39	1.319

Example. A figure 8 coil is 5 ins. in diameter and 0.5 ins. long, wound 40 turns per inch. The value in the "5 ins." column, opposite "0.5 in." is 60.79. This multiplied by 40^2 is

$$60.79 \times 1,600 = 97,264 \text{ cms.}$$

The length divided by the diameter is

$$0.5 \div 5 = 0.1,$$

the constant of which, from the table, is 1.55. Then the inductance of the figure 8 coil is

$$97,264 \times 1.55 = 150,759 \text{ cms.}$$

Inductance of Pancake Coils

In figuring the inductance of pancake coils, one turn thick, the diameter is taken as the average of the inside and outside diameters, the length as the difference between the inside and outside radii, and the turns per inch as measured radially across the coil. These values are applied to the Inductance Table.

Example. 500,000 cms. inductance are required of a coil having an average diameter of 5 ins. wound with wire giving 30 turns per inch. To find the required difference between the inside and outside radii:

The inductance divided by the turns per inch squared is

$$500,000 \div 900 = 555$$

In the column headed "5 Ins." the nearest value is 550.4, opposite "1.9 Ins." length. Therefore the difference between the inside and outside radii is 1.9 ins. The average radius is one-half the average diameter, or 2.5 ins. To find the outside and inside radii, one-half of 1.9 is added to and subtracted from 2.5 ins.

$$2.5 + 0.95 = 3.45 \text{ ins. outside radius.}$$
$$2.5 - 0.95 = 1.55 \text{ ins. inside radius.}$$

Use of the Calculations

To illustrate one way in which these calculations can be used, let us design a loose coupler to tune from 200 to 900 meters, using an antenna of 0.0003 mfd., the average value, and primary and secondary shunt condensers of 0.0001 to 0.001 mfd.

The effective capacity in the primary circuit is 0.0004 to 0.0013 mfd. From the tables previously shown, the following values of inductance are required:

Primary Circuit

Wavelength with 0.0004 mfd.	Wavelength with 0.0013 mfd.
Tap 1: 25,000 cms.	
188 meters	340 meters
Tap 2: 70,000 cms.	
315 meters	569 meters
Tap 3: 180,000 cms.	
506 meters	912 meters

The effective capacity in the secondary circuit is 0.0001 to 0.001 mfd.

Secondary Circuit

Wavelength with 0.0001 mfd.	Wavelength with 0.001 mfd.
Tap 1: 50,000 cms.	
133 meters	421 meters
Tap 2: 250,000 cms.	
298 meters	942 meters

If No. 24 S. S. C. wire, giving 44 turns per inch, is wound on a tube 3.5 ins. in diameter, taps must be taken off at the following lengths measuring from the start of the winding:

Tap 1, 25,000 cms., 0.3 in., 13th turn
Tap 2, 70,000 cms., 0.5 in., 22nd turn
Tap 3, 180,000 cms., 0.85 in., 37th turn

The secondary, on a 3-in. tube, will be tapped:

Tap 1, 50,000 cms., 0.45 in., 20th turn
Tap 2, 250,000 cms., 1.2 ins., 53rd turn

Here, then, is the complete data for a 200- to 900-meter loose coupler, all of which was figured in less than 5 minutes, while without the table very rough guesses would have been made, with final results far from those expected. On tap 1 of the primary, the condenser tunes from 188 to 340 meters; on tap 2, 315 to 569 meters, etc.

In designing tapped coils of this sort the length for a given inductance is always figured from the start of the winding, and not from the previous tap.

The following will be found helpful:
1,000,000 cms. = 1 millihenry
1,000 millihenries = 1 henry
1 cm. = 0.000001 millihenry.

Ins. long	Inches 3.00	Inches 3.25	Inches 3.50	Inches 3.75	Inches 4.00	Inches 4.25	Inches 4.50	Inches 4.75	Inches 5.00	Inches 5.25	Inches 5.50	Inches 5.75	Inches 6.00	Inches 6.25	Inches 6.50
.1	2.052	2.252	2.479	2.672	2.918	3.084	3.368	3.453	3.826	4.119	4.251	4.373	4.761	5.107	5.243
.2	6.887	7.710	8.200	9.046	9.908	11.19	11.78	12.59	13.21	14.02	14.53	15.29	16.01	16.65	17.10
.3	13.75	15.11	16.48	20.99	20.34	21.79	23.24	24.70	26.19	27.67	30.37	31.90	32.68	35.62	36.55
.4	17.69	25.05	26.82	29.67	32.59	34.79	38.61	40.47	42.39	46.73	48.65	53.17	54.45	57.03	61.68
.5	32.18	35.87	39.65	43.49	47.44	51.40	55.42	56.84	60.79	65.70	72.10	74.13	80.71	82.78	89.54
.6	43.27	47.86	52.55	57.30	65.19	70.15	75.15	80.27	85.37	90.52	99.34	104.7	110.0	119.4	120.8
.7	54.77	62.31	71.93	74.35	84.59	90.39	98.51	102.2	113.8	119.7	125.6	137.2	142.9	149.7	156.0
.8	68.27	76.24	84.82	93.59	102.5	109.1	122.4	129.0	135.8	149.7	156.7	171.2	178.1	185.3	200.4
.9	82.70	92.44	102.4	110.0	123.0	135.2	146.0	153.4	169.9	177.3	194.6	202.1	220.0	227.6	246.2
1.0	96.79	107.8	121.0	132.6	146.5	157.0	172.9	185.3	200.3	208.2	228.5	236.4	257.4	265.3	286.9
1.1	112.6	124.9	139.9	152.8	171.1	184.5	201.1	215.5	231.7	249.0	266.6	291.3	299.1	324.5	332.3
1.2	127.7	144.1	160.9	178.2	196.0	214.1	229.1	247.8	266.9	286.3	310.6	325.9	346.1	375.5	382.9
1.3	144.2	162.3	181.0	200.1	219.7	239.7	260.1	280.8	301.8	328.0	360.0	372.0	394.4	417.1	440.0
1.4	162.2	182.2	202.7	223.7	245.2	271.9	294.4	317.1	340.4	369.4	399.3	417.7	438.1	466.9	498.5
1.5	177.7	198.6	226.4	249.4	272.8	302.2	326.6	351.4	382.8	408.5	441.2	467.6	494.3	521.2	550.9
1.6	194.1	222.5	246.7	277.2	302.6	328.5	361.3	388.1	422.5	450.2	485.9	514.4	543.4	580.4	610.1
1.7	213.9	241.9	274.2	303.3	328.1	363.0	391.2	427.8	464.8	495.0	534.6	564.3	604.6	635.2	677.2
1.8	232.2	262.5	293.6	325.7	362.5	392.0	430.9	470.0	501.8	543.1	575.2	617.9	661.5	694.7	739.5
1.9	248.3	284.0	317.4	355.8	391.2	432.0	465.2	506.7	550.4	595.2	629.2	675.4	710.2	757.6	804.1
2.0	268.4	302.7	342.4	379.0	421.2	464.9	498.9	544.4	591.1	638.8	674.7	723.9	774.1	827.2	862.6
2.1	286.9	326.4	370.4	407.7	452.7	499.3	547.2	583.7	633.4	684.2	736.1	789.1	827.6	882.0	937.2
2.2	307.6	346.3	391.3	437.8	485.9	529.2	573.9	624.8	677.9	731.6	786.7	842.9	900.1	936.6	999.3
2.3	319.0	372.1	419.8	463.5	514.3	566.6	620.2	667.8	723.8	781.0	839.4	898.9	959.4	1021.	1084.
2.4	353.4	393.6	444.2	496.6	550.3	592.1	662.8	712.8	772.1	832.7	894.4	957.3	1021.	1086.	1152.
2.5	365.0	416.1	469.1	524.0	576.8	639.0	698.9	760.0	822.7	886.7	951.9	1018.8	1086.	1154.	1224.
2.6	387.1	439.0	494.7	551.1	611.9	673.0	735.8	800.0	875.8	943.3	1012.	1082.	1153.	1225.	1299.
2.7	408.1	462.0	521.2	581.6	643.9	717.4	783.5	851.4	920.5	991.0	1075.	1149.	1224.	1299.	1376.
2.8	429.2	487.0	548.3	611.6	676.8	753.8	823.1	894.0	966.4	1040.	1128.	1191.	1297.	1377.	1457.
2.9	445.2	512.0	576.2	642.6	710.8	791.4	863.8	937.7	1026.	1104.	1182.	1262.	1343.	1426.	1541.
3.0	467.8	529.7	605.1	674.3	745.6	830.1	905.5	982.6	1075.	1156.	1238.	1321.	1422.	1508.	1595.
3.1	488.0	555.9	625.3	707.1	781.5	869.8	948.4	1029.	1125.	1209.	1295.	1381.	1486.	1594.	1685.
3.2	508.7	582.0	655.3	740.9	818.1	897.8	992.6	1076.	1177.	1264.	1370.	1461.	1552.	1645.	1780.
3.3	529.6	604.9	685.3	764.1	856.4	939.7	1038.	1125.	1230.	1320.	1431.	1525.	1620.	1737.	1835.
3.4	551.2	627.8	707.1	799.2	882.4	981.7	1085.	1175.	1284.	1378.	1493.	1591.	1690.	1811.	1936.
3.5	571.1	649.2	739.4	835.6	922.1	1025.	1117.	1227.	1322.	1438.	1537.	1658.	1761.	1887.	2017.
3.6	593.4	677.1	767.8	859.4	962.8	1055.	1165.	1280.	1379.	1499.	1602.	1728.	1834.	1965.	2100.
3.7	614.0	700.7	794.2	897.4	989.6	1100.	1215.	1315.	1437.	1562.	1667.	1776.	1909.	2044.	2185.
3.8	634.8	724.3	823.6	924.4	1032.	1147.	1248.	1370.	1497.	1604.	1737.	1848.	1986.	2100.	2267.
3.9	656.0	750.9	851.1	958.0	1059.	1178.	1300.	1427.	1535.	1670.	1807.	1922.	2065.	2183.	2361.
4.0	677.5	775.4	878.5	988.9	1104.	1226.	1334.	1464.	1598.	1737.	1853.	1998.	2146.	2268.	2453.
4.1	699.3	800.2	909.4	1033.	1142.	1257.	1388.	1523.	1663.	1781.	1927.	2076.	2200.	2325.	2514.
4.2	721.3	825.8	935.7	1055.	1178.	1308.	1444.	1560.	1703.	1850.	2002.	2127.	2284.	2413.	2610.
4.3	740.3	847.8	966.7	1088.	1208.	1344.	1487.	1622.	1770.	1922.	2050.	2208.	2371.	2504.	2708.
4.4	763.7	873.9	992.6	1120.	1250.	1384.	1536.	1659.	1811.	1967.	2128.	2292.	2427.	2562.	2771.
4.5	783.8	899.9	1022.	1154.	1286.	1429.	1571.	1728.	1881.	2042.	2208.	2344.	2516.	2656.	2872.
4.6	807.0	922.8	1049.	1183.	1324.	1470.	1617.	1762.	1922.	2088.	2257.	2396.	2566.	2752.	2977.
4.7	827.4	949.4	1079.	1217.	1362.	1512.	1662.	1820.	1994.	2165.	2340.	2484.	2666.	2812.	3042.
4.8	848.0	975.2	1109.	1251.	1400.	1549.	1709.	1874.	2037.	2212.	2391.	2537.	2723.	2913.	3150.
4.9	872.0	1000.0	1140.	1282.	1434.	1592.	1756.	1925.	2112.	2293.	2478.	2628.	2820.	2972.	3216.
5.0	893.0	1025.0	1166.	1317.	1473.	1635.	1803.	1977.	2156.	2340.	2528.	2681.	2877.	3077.	3329.

5.1	910.2	1049	1195	1348	1513	1679	1852	2021	2213	2383	2579	2776	2981	3188	3448
5.2	931.4	1073	1227	1384	1548	1718	1894	2083	2271	2472	2670	2831	3082	3247	3512
5.3	952.8	1102	1255	1416	1583	1763	1943	2130	2330	2535	2722	2929	3142	3358	3579
5.4	974.3	1127	1283	1452	1624	1802	1993	2184	2371	2591	2817	2984	3201	3421	3701
5.5	996.1	1152	1312	1485	1660	1848	2037	2240	2441	2648	2869	3087	3310	3485	3769
5.6	1018	1177	1340	1517	1702	1888	2088	2288	2502	2714	2940	3143	3370	3602	3896
5.7	1040	1202	1374	1553	1736	1929	2133	2344	2555	2780	3002	3250	3484	3666	3965
5.8	1062	1228	1403	1582	1775	1976	2177	2393	2617	2838	3074	3317	3545	3787	4096
5.9	1084	1254	1433	1615	1812	2017	2230	2443	2671	2906	3134	3396	3663	3852	4167
6.0	1107	1280	1462	1649	1849	2058	2276	2501	2734	2965	3211	3465	3725	3979	4237
6.1	1130	1306	1492	1682	1887	2098	2322	2552	2789	3034	3286	3546	3811	4045	4375
6.2	1152	1332	1522	1716	1925	2142	2368	2602	2845	3094	3351	3600	3886	4176	4447
6.3	1172	1354	1547	1750	1962	2192	2423	2663	2910	3165	3428	3697	3974	4257	4519
6.4	1194	1380	1577	1784	2001	2235	2468	2714	2966	3226	3493	3768	4050	4339	4663
6.5	1217	1407	1608	1818	2039	2278	2517	2706	3023	3288	3560	3853	4140	4435	4736
6.6	1236	1434	1638	1853	2078	2321	2564	2818	3080	3350	3639	3925	4217	4517	4824
6.7	1260	1456	1669	1888	2113	2365	2614	2871	3138	3424	3707	3998	4296	4596	4928
6.8	1283	1483	1694	1924	2155	2400	2662	2921	3196	3487	3775	4071	4389	4689	5018
6.9	1302	1511	1726	1959	2196	2444	2711	2977	3254	3550	3844	4159	4469	4784	5125
7.0	1326	1538	1757	1988	2237	2489	2760	3032	3324	3614	3912	4233	4548	4885	5194
7.1	1350	1560	1789	2023	2277	2533	2809	3086	3380	3678	3982	4308	4628	4972	5295
7.2	1369	1588	1814	2059	2309	2578	2849	3140	3442	3743	4066	4384	4725	5059	5418
7.3	1394	1610	1845	2096	2350	2624	2899	3195	3503	3808	4137	4460	4806	5146	5511
7.4	1413	1638	1879	2125	2391	2670	2949	3251	3564	3874	4208	4537	4889	5251	5605
7.5	1438	1667	1904	2161	2432	2705	3000	3306	3612	3936	4279	4613	4973	5341	5699
7.6	1457	1689	1937	2198	2466	2751	3051	3350	3673	4006	4351	4691	5055	5430	5794
7.7	1481	1718	1970	2222	2506	2798	3091	3407	3735	4074	4424	4769	5139	5520	5910
7.8	1501	1740	1995	2265	2548	2834	3143	3464	3796	4141	4493	4848	5223	5611	6007
7.9	1526	1770	2029	2294	2581	2881	3195	3521	3859	4195	4550	4927	5309	5702	6104
8.0	1545	1792	2055	2332	2623	2928	3247	3578	3908	4263	4628	5006	5395	5794	6203
8.1	1570	1821	2088	2366	2666	2965	3287	3623	3971	4332	4704	5087	5481	5886	6302
8.2	1590	1844	2114	2399	2699	3013	3340	3681	4035	4400	4778	5162	5568	5979	6401
8.3	1616	1873	2148	2438	2742	3061	3394	3740	4099	4470	4854	5248	5656	6074	6501
8.4	1635	1896	2174	2467	2775	3098	3434	3785	4148	4524	4930	5331	5743	6168	6602
8.5	1661	1926	2208	2506	2819	3146	3488	3844	4213	4594	4989	5395	5826	6241	6680
8.6	1680	1949	2234	2535	2852	3196	3542	3900	4273	4661	5065	5478	5895	6337	6783
8.7	1700	1979	2269	2575	2896	3233	3584	3949	4328	4736	5142	5561	5990	6433	6886
8.8	1726	2002	2295	2604	2930	3282	3639	4009	4393	4791	5201	5645	6081	6529	6989
8.9	1746	2025	2330	2644	2974	3319	3680	4069	4459	4863	5279	5706	6172	6618	7093
9.0	1773	2056	2356	2674	3019	3359	3735	4115	4510	4936	5359	5793	6241	6723	7197
9.1	1792	2078	2382	2711	3052	3407	3776	4176	4577	4991	5437	5879	6333	6798	7302
9.2	1812	2109	2418	2738	3086	3458	3832	4222	4644	5064	5497	5943	6426	6899	7383
9.3	1839	2132	2444	2784	3131	3495	3889	4284	4694	5119	5577	6030	6495	6998	7481
9.4	1858	2155	2480	2814	3165	3546	3931	4330	4762	5193	5658	6117	6588	7098	7595
9.5	1878	2187	2507	2844	3211	3584	3987	4393	4813	5268	5718	6182	6682	7174	7705
9.6	1906	2210	2543	2885	3245	3625	4029	4439	4882	5323	5799	6269	6753	7274	7786
9.7	1926	2233	2569	2915	3291	3673	4087	4502	4933	5398	5860	6358	6848	7377	7895
9.8	1945	2265	2596	2957	3325	3725	4129	4549	5003	5454	5942	6424	6944	7453	8004
9.9	1973	2288	2632	2987	3372	3763	4187	4612	5054	5530	6002	6513	7015	7556	8086
10.0	1993	2311	2659	3017	3406	3801	4229	4659	5123	5586	6086	6579	7111	7632	8197

Ins. long	Inches 6.75	Inches 7.00	Inches 7.25	Inches 7.50	Inches 7.75	Inches 8.00	Inches 8.25	Inches 8.50	Inches 8.75	Inches 9.00	Inches 9.25	Inches 9.50	Inches 9.75	Inches 10.00
.1	5.330	5.732	6.108	6.204	6.304	6.717	7.048	7.196	7.307	7.729	8.065	8.173	8.335	8.768
.2	18.44	19.84	20.38	21.02	21.91	23.34	24.19	25.26	26.07	26.83	27.35	27.83	29.00	30.61
.3	36.91	39.79	42.58	42.91	45.81	46.12	49.77	52.07	53.36	55.39	58.51	61.72	57.72	60.72
.4	63.64	65.60	70.37	72.37	77.28	79.26	83.52	85.52	88.30	87.49	92.42	97.48	102.7	104.9
.5	91.59	98.51	100.5	107.6	109.6	116.8	120.6	155.2	133.7	135.2	137.6	145.2	147.2	154.8
.6	130.3	131.8	141.4	151.3	152.8	162.6	166.6	174.3	175.7	185.9	196.4	202.2	208.2	209.5
.7	168.3	174.7	187.4	192.1	200.4	213.6	216.6	227.2	233.2	240.2	247.9	254.0	267.0	281.4
.8	207.6	214.6	230.2	237.4	253.5	260.7	281.4	292.0	299.0	308.9	316.9	323.7	332.0	340.1
.9	253.6	272.8	280.5	288.2	307.7	315.3	340.2	351.8	363.6	371.3	377.1	387.2	407.9	429.0
1.0	294.9	317.1	325.1	347.9	356.1	379.5	393.0	410.3	419.1	443.3	451.4	476.1	481.1	509.3
1.1	358.3	366.0	392.7	400.5	427.7	435.4	469.8	491.5	499.2	528.3	535.7	565.0	572.3	602.1
1.2	412.9	420.4	440.7	458.4	489.5	521.6	536.4	561.1	568.2	602.5	635.0	642.1	676.3	683.0
1.3	474.5	481.1	516.1	522.8	558.2	594.8	609.7	637.9	691.7	681.6	720.0	725.6	764.3	802.0
1.4	523.9	549.6	589.5	594.8	635.1	676.7	691.2	723.2	727.9	772.1	813.5	817.8	851.3	905.2
1.5	583.6	611.5	647.6	675.9	721.7	725.1	782.3	818.5	821.1	870.6	926.0	949.3	958.4	1019.
1.6	648.5	678.6	718.2	748.7	789.4	820.3	885.1	905.1	925.2	978.8	987.7	1032	1087	1144.
1.7	709.0	751.6	790.7	827.8	860.2	905.0	964.3	984.0	1043	1073	1099	1159	1201	1235.
1.8	773.3	819.0	866.0	900.6	939.7	997.0	1048.	1082.	1118	1168	1234	1267	1292	1359.
1.9	841.8	891.4	941.6	992.4	1030	1082	1141.	1172.	1226	1264	1319	1374	1427	1465.
2.0	914.9	968.2	1022	1077	1115	1172	1246.	1298.	1356	1387	1442	1483	1542	1602.
2.1	993.5	1050	1091	1149	1208	1267	1347	1369	1464	1479	1555	1618	1682	1725.
2.2	1059	1119	1180	1242	1305	1369	1455	1472	1538	1608	1674	1725	1810	1854.
2.3	1147	1212	1255	1321	1387	1453	1545	1581	1661	1730	1801	1873	1943	1991.
2.4	1220	1288	1336	1426	1497	1558	1664	1713	1787	1833	1907	1983	2059	2135.
2.5	1295	1366	1439	1512	1586	1661	1762	1814	1935	1969	2048	2127	2207	2288.
2.6	1373	1448	1524	1601	1679	1758	1864	1917	1999	2080	2163	2247	2330	2412.
2.7	1454	1533	1613	1694	1775	1858	1970	2025	2146	2232	2320	2407	2496	2585.
2.8	1539	1622	1706	1790	1876	1962	2079	2175	2265	2357	2445	2537	2630	2723.
2.9	1594	1675	1802	1890	1980	2070	2192	2294	2387	2481	2576	2672	2768	2865.
3.0	1684	1811	1902	1995	2088	2182	2310	2362	2514	2613	2712	2811	2911	3062.
3.1	1778	1871	2007	2104	2201	2299	2433	2546	2647	2749	2852	2955	3113	3219.
3.2	1876	1974	2072	2218	2319	2421	2561	2622	2785	2897	2997	3098	3271	3380.
3.3	1979	2081	2183	2287	2442	2548	2694	2757	2896	2969	3149	3240	3373	3548.
3.4	2039	2144	2300	2407	2516	2625	2833	2904	3086	3191	3306	3422	3538	3722.
3.5	2124	2258	2360	2533	2636	2762	2916	3051	3168	3293	3470	3590	3711	3831.
3.6	2210	2322	2491	2606	2722	2900	3063	3137	3325	3447	3570	3765	3889	4015.
3.7	2327	2443	2590	2740	2860	2981	3216	3293	3418	3615	3742	3870	4076	4195.
3.8	2390	2539	2691	2846	3004	3130	3303	3456	3566	3713	3922	4054	4186	4404.
3.9	2483	2638	2796	2956	3084	3212	3465	3555	3759	3901	4026	4246	4333	4519.
4.0	2579	2739	2903	3032	3199	3370	3555	3719	3855	3992	4216	4355	4587	4728.
4.1	2677	2843	3012	3145	3318	3470	3727	3892	4039	4180	4322	4559	4702	4945.
4.2	2778	2949	3085	3261	3440	3622	3859	3995	4234	4378	4524	4670	4919	5067.
4.3	2882	3020	3197	3380	3565	3753	4001	4160	4334	4482	4631	4885	5036	5298.
4.4	2949	3130	3314	3502	3693	3896	4094	4233	4434	4692	4845	5068	5265	5421.
4.5	3056	3243	3434	3628	3825	3976	4238	4381	4588	4798	4955	5226	5385	5665.
4.6	3166	3315	3510	3708	3909	4114	4385	4532	4745	4916	5181	5342	5627	5790.
4.7	3235	3433	3633	3838	4046	4257	4536	4688	4987	5130	5355	5584	5749	6047.
4.8	3350	3553	3761	3972	4185	4403	4691	4847	5073	5239	5469	5702	6007	6321.
4.9	3420	3627	3839	4054	4272	4494	4783	4948	5179	5413	5649	5889	6132	6450.
5.0	3539	3753	3971	4182	4417	4645	4948	5112	5350	5721	5834	6080	6329	6582.

5.1	3664	3886	4110	4338	4570	4756	5118	5266	5531	5779	6030	6283	6539	6791
5.2	3732	3958	4187	4419	4655	4895	5213	5384	5634	5886	6142	6400	6661	7007
5.3	3860	4092	4327	4567	4809	5056	5384	5572	5815	6072	6338	6603	6871	7142
5.4	3933	4169	4409	4653	4900	5151	5485	5752	6002	6268	6538	6811	7087	7364
5.5	4065	4308	4555	4806	5060	5318	5661	5844	6113	6384	6659	6937	7307	7593
5.6	4138	4386	4638	4893	5152	5415	5841	6031	6307	6585	6867	7152	7440	7731
5.7	4212	4465	4789	5052	5318	5588	5947	6124	6419	6702	7080	7372	7657	7966
5.8	4351	4610	4873	5142	5411	5686	6135	6331	6619	6800	7204	7502	7802	8105
5.9	4426	4689	4957	5305	5584	5865	6241	6440	6733	7030	7426	7730	8038	8345
6.0	4501	4841	5115	5395	5678	5964	6347	6641	6840	7244	7552	7859	8280	8599
6.1	4646	4922	5201	5485	5856	6151	6543	6751	7056	7365	7779	8061	8418	8742
6.2	4722	5002	5366	5657	5952	6252	6651	6958	7272	7587	7907	8231	8659	9000
6.3	4873	5160	5452	5748	6048	6445	6855	7071	7389	7710	8144	8474	8809	9145
6.4	4950	5242	5539	5928	6235	6547	6964	7183	7612	7941	8273	8609	9068	9414
6.5	5028	5324	5711	6020	6332	6649	7175	7400	7730	8065	8539	8862	9210	9561
6.6	5185	5490	5799	6062	6527	6851	7285	7514	7849	8304	8650	8999	9351	9837
6.7	5264	5573	5900	6300	6626	6955	7396	7738	8083	8430	8781	9262	9622	9986
6.8	5360	5657	6068	6394	6725	7059	7617	7853	8203	8699	9038	9401	9766	10270
6.9	5456	5830	6157	6488	6928	7271	7729	7969	8444	8806	9171	9540	10050	10420
7.0	5571	5915	6246	6685	7028	7377	7841	8203	8567	8934	9437	9813	10190	10580
7.1	5668	6019	6436	6780	7128	7482	8073	8321	8689	9193	9572	9953	10480	10870
7.2	5767	6142	6526	6873	7229	7703	8187	8438	8941	9322	9707	10240	10530	11030
7.3	5841	6248	6638	6971	7443	7810	8300	8684	9065	9452	9984	10380	10780	11340
7.4	5985	6353	6750	7178	7545	7917	8542	8803	9190	9724	10120	10520	11080	11490
7.5	6086	6454	6863	7275	7647	8149	8657	8922	9454	9854	10260	10820	11240	11650
7.6	6187	6589	6999	7396	7872	8257	8773	9179	9581	9985	10550	10960	11380	11970
7.7	6290	6697	7115	7541	7975	8366	9027	9299	9707	10270	10690	11110	11700	12130
7.8	6392	6807	7200	7629	8105	8475	9144	9420	9983	10400	10820	11420	11850	12290
7.9	6517	6907	7347	7786	8235	8719	9261	9541	10110	10540	11130	11560	12000	12630
8.0	6622	7028	7464	7911	8365	8829	9379	9813	10240	10830	11270	11710	12340	12790
8.1	6727	7163	7583	8002	8498	8968	9646	9935	10370	10970	11410	12040	12490	12950
8.2	6833	7275	7727	8161	8629	9012	9765	10130	10660	11100	11550	12190	12640	13300
8.3	6940	7388	7848	8315	8755	9279	9916	10340	10790	11240	11870	12330	12990	13460
8.4	7048	7503	7968	8443	8926	9420	10070	10490	10920	11550	12010	12480	13150	13630
8.5	7156	7618	8090	8574	9064	9564	10220	10590	11050	11690	12160	12820	13300	13790
8.6	7240	7734	8212	8721	9200	9666	10370	10750	11350	11830	12300	12970	13470	14150
8.7	7349	7824	8336	8831	9337	9852	10530	10930	11490	11960	12640	13120	13820	14320
8.8	7458	7940	8460	8963	9476	9997	10680	11070	11660	12290	12780	13280	13980	14490
8.9	7570	8058	8556	9095	9614	10140	10790	11210	11830	12450	12930	13640	14140	14880
9.0	7681	8176	8682	9228	9755	10290	11000	11430	12000	12580	13070	13790	14300	15040
9.1	7794	8295	8808	9362	9896	10440	11150	11550	12170	12750	13430	13940	14690	15210
9.2	7907	8415	8935	9465	10040	10597	11310	11760	12340	12930	13770	14090	14850	15380
9.3	7992	8537	9063	9600	10180	10740	11480	11960	12520	13110	13930	14470	15010	15550
9.4	8106	8628	9191	9737	10330	10890	11640	12100	12640	13300	14150	14630	15170	15960
9.5	8221	8750	9321	9874	10440	11050	11800	12220	12870	13480	14300	14780	15330	16130
9.6	8328	8873	9420	10010	10580	11200	11960	12390	13050	13700	14350	14990	15740	16300
9.7	8415	8996	9551	10150	10730	11320	12130	12560	13230	13800	14540	15190	15900	16600
9.8	8539	9121	9683	10250	10880	11470	12290	12740	13410	14050	14740	15400	16060	16900
9.9	8659	9214	9816	10400	11020	11630	12460	12910	13600	14230	14880	15610	16280	17070
10.0	8777	9330	9915	10540	11140	11780	12590	13040	13730	14430	15030	15810	16500	17240