

Workshop Practice

IN CONTRAST to the earlier days of amateur radio, when many components were obtainable only at prohibitive prices or not at all, the construction of a piece of equipment these days resolves itself chiefly into the proper assembly and wiring of manufactured components from the wide assortment available.

Tools

While an easier, and perhaps a better, job can be done with a greater variety of tools available, by taking a little thought and care it is possible to turn out a fine piece of equipment with only a few of the common hand tools. A list of tools which will be found indispensable in the construction of radio equipment will be found on the next page. With these tools it should be possible to perform any of the required operations in preparing panels and metal chassis for assembly and wiring. A few additional tools will make certain operations easier, so it is a good idea for the amateur who does constructional work at intervals to add to his supply of tools from time to time. The following list will be found helpful in making a selection:

Bench vise, 4-inch jaws.

Tin shears, 10-inch, for cutting thin sheet metal.

Taper reamer, 1/2-inch, for enlarging small holes.

Taper reamer, 1-inch, for enlarging holes.

Countersink for brace.

Carpenter's plane, 8- to 12-inch, for wood-working.

Carpenter's saw, cross-cut.

Motor-driven emery wheel for grinding.

Long-shank screwdriver with screw-holding clip for tight places.

Set of "Spintite" socket wrenches for hex nuts.

Set of small, flat, open-end wrenches for hex nuts.

Wood chisel, 1/2-inch.

Cold chisel, 1/2-inch.

Wing dividers, 8-inch, for scribing circles.

Set of machine-screw taps and dies.

Folding rule, 6-foot.

Dusting brush.

Several of the pieces of light woodworking machinery, often sold in hardware stores and mail-order retail stores, are ideal for amateur radio work, especially the drill press, grinding head, band and circular saws, and joiner. Although not essential, they are desirable for anyone in a position to acquire them.

Care of Tools

The proper care of tools is not alone a matter of pride to a good workman. He also realizes the energy which may be saved and the annoyance which may be avoided by the possession of well-kept, sharp-edged tools. A few minutes spent with the oil stone or emery wheel now and then will maintain the fine cutting edges of knives, drills, chisels, etc.

Drills should be sharpened at frequent intervals so that grinding is kept at a minimum each time. This makes it easier to maintain the rather critical surface angles required for best cutting with least wear. Occasional oil-stoning of the cutting edges of a drill or reamer will extend the time between grindings. Stoned cutting edges also will stand more feed and speed.

The soldering iron can be kept in good condition by keeping the tip well tinned with solder and not allowing it to run at full voltage for long periods when it is not being used. After each period of use, the tip should be removed and cleaned of any scale which may have accumulated. An oxidized tip may be cleaned by dipping it in sal ammoniac while hot and then wiping it clean with a rag. If the tip becomes pitted, it should be filed until smooth and bright, and then tinned by dipping it in solder.

All tools should be wiped occasionally with an oily cloth to prevent rust.

INDISPENSABLE TOOLS

Long-nose pliers, 6-inch.

Diagonal cutting pliers, 6-inch.

Screwdriver, 6- to 7-inch, 1/4-inch blade.

Screwdriver, 4- to 5-inch, 1/8-inch blade.

Scratch awl or scriber for marking lines.

Combination square, 12-inch, for laying out work.

Hand drill, 1/4-inch chuck or larger, 2-speed type preferable.

Electric soldering iron, 100 watts.

Hacksaw, 12-inch blades.

Center punch for marking hole centers.

Hammer, ball peen, 1-lb. head.

Heavy knife.

Yardstick or other straight-edge.

Carpenter's brace with adjustable hole cutter or socket-hole punches (see text).

Pair of small C-clamps for holding work.

Large, coarse, flat file.

Large round or rat-tail file, 1/2-inch diameter.

Three or four small and medium files—flat, round, half-round, triangular.

Drills, particularly 1/4-inch and Nos. 18, 28, 33, 42 and 50.

Combination oil stone for sharpening tools.

Solder and soldering paste (non-corroding).

Medium-weight machine oil.

Useful Materials

Small stocks of various miscellaneous materials will be required in constructing radio apparatus, most of which are available from hardware or radio supply stores. A representative list follows:

1/2-inch by 1/16-inch brass strip for brackets, etc. (half-hard for bending).

1/4-inch square brass rod or 1/2 x 1/2 x 1/16-inch angle brass for corner joints.

1/4-inch diameter round brass rod for shaft extensions.

Machine screws: Round-head and flat-head, with nuts to fit. Most useful sizes: 4-36, 6-32 and 8-32, in lengths from 1/4-inch to 1 1/2-inch. (Nickel-plated iron will be found satisfactory except in strong r.f. fields, where brass should be used.)

Bakelite and hard rubber scraps.

Soldering lugs, panel bearings, rubber grommets, terminal-lug wiring strips, varnished-cambric insulating tubing.

Machine screws, nuts, washers, soldering lugs, etc., are most reasonably purchased in quantities of a gross.

Chassis Construction

With a few essential tools and proper procedure, it will be found that building radio gear on a metal chassis is no more of a chore than building with wood, and a more satisfactory job results.

The placing of components on the chassis is shown quite clearly in the photographs in this *Handbook*. Aside from certain essential dimensions, which usually are given in the text, exact duplication is not necessary.

Much trouble and energy can be saved by spending sufficient time in planning the job. When all details are worked out beforehand the actual construction is greatly simplified.

Cover the top of the chassis with a piece of wrapping paper or, preferably, cross-section paper, folding the edges down over the sides of the chassis and fastening with adhesive tape. Then assemble the parts to be mounted on top of the chassis and move them about until a satisfactory arrangement has been found, keeping in mind any parts which are to be mounted underneath, so that interferences in mounting may be avoided. Place condensers and other parts with shafts extending through the panel first, and arrange them so that the controls will form the desired pattern on the panel. Be sure to line up the shafts squarely with the chassis front. Locate any partition shields and panel brackets next, and then the tube sockets and any other parts, marking the mounting-hole centers of each accurately on the paper. Watch out for condensers whose shafts do not line up with the mounting holes. Do not forget to mark the centers of socket holes and holes for leads under i.f. transformers, etc., as well as holes for wiring leads.

NUMBERED DRILL SIZES

Number	Diameter (mils)	Will Clear Screw	Drilled for Tapping Iron, Steel or Brass*
1	228.0	—	—
2	221.0	12-24	—
3	213.0	—	14-24
4	209.0	12-20	—
5	205.0	—	—
6	204.0	—	—
7	201.0	—	—
8	199.0	—	—
9	196.0	—	—
10	193.5	10-32	—
11	191.0	10-24	—
12	189.0	—	—
13	185.0	—	—
14	182.0	—	—
15	180.0	—	—
16	177.0	—	12-24
17	173.0	—	—
18	169.5	8-32	—
19	166.0	—	12-20
20	161.0	—	—
21	159.0	—	10-32
22	157.0	—	—
23	154.0	—	—
24	152.0	—	—
25	149.5	—	10-24
26	147.0	—	—
27	144.0	—	—
28	140.0	6-32	—
29	136.0	—	8-32
30	128.5	—	—
31	120.0	—	—
32	116.0	—	—
33	113.0	4-36 4-40	—
34	111.0	—	—
35	110.0	—	6-32
36	106.5	—	—
37	104.0	—	—
38	101.5	—	—
39	99.5	3-48	—
40	99.0	—	—
41	96.0	—	—
42	93.5	—	4-36 4-40
43	89.0	2-56	—
44	86.0	—	—
45	82.0	—	3-48
46	81.0	—	—
47	78.5	—	—
48	76.0	—	—
49	73.0	—	2-46
50	70.0	—	—
51	67.0	—	—
52	63.5	—	—
53	59.5	—	—
54	55.0	—	—

*Use one size larger for tapping bakelite and hard rubber.

By means of the square, lines indicating accurately the centers of shafts should be extended to the front of the chassis and marked on the panel at the chassis line, the panel being fastened on temporarily. The hole centers may then be punched in the chassis with the center punch. After drilling, the parts which require mounting underneath may be located and the mounting holes drilled, making sure by trial that no interferences exist with parts mounted on top. Mounting holes along the front edge of the chassis should be transferred to the panel, by once again fastening the panel to the chassis and marking it from the rear.

Next, mount on the chassis the condensers and any other parts with shafts extending to the panel, and measure accurately the height

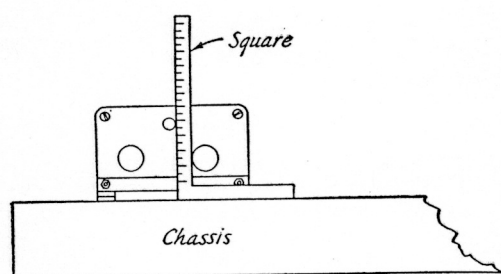


Fig. 2001 — Method of measuring the heights of condenser shafts, etc. If the square is adjustable, the end of the scale should be set flush with the face of the head.

of the center of each shaft above the chassis, as illustrated in Fig. 2001. The horizontal displacement of shafts having already been marked on the chassis line on the panel, the vertical displacement can be measured from this line. The shaft centers may now be marked on the back of the panel, and the holes drilled. Holes for any other panel equipment coming above the chassis line may then be marked and drilled, and the remainder of the apparatus mounted.

Drilling and Cutting Holes

When drilling holes in metal with a hand drill it is important that the centers first be located with a center punch, so that the drill point will not "walk" away from the center when starting the hole. Care should be taken not to use too much pressure with small drills, which bend or break easily. Whenever the drill starts to break through, special care must be used. Often it is an advantage to shift a two-speed drill to low gear at this point. Holes more than $\frac{1}{4}$ -inch in diameter may be started with a smaller drill and reamed out with the larger drill.

The chuck on the usual type of hand drill is limited to $\frac{1}{4}$ -inch drills. Although it is rather tedious, the $\frac{1}{4}$ -inch hole may be filed out to larger diameters with round files. Another method possible with limited tools is to drill a series of small holes with the hand drill along the inside of the diameter of the large hole, placing the holes as close together as possible. The center may then be knocked out with a cold chisel and the edges smoothed up with a file. Taper reamers which fit into the carpenter's brace will make the job easier. A large rat-tail file clamped in the brace makes a very good reamer for holes up to the diameter of the file, if the file is revolved counter-clockwise.

For socket holes and other large round holes, an adjustable cutter designed for the purpose may be used in the brace. The cutter should be kept well-sharpened. Occasional application of machine oil in the cutting groove will help. The cutter first should be tried out on a block of wood, to make sure that it is set for the correct diameter. Probably the most convenient device for cutting socket holes is the socket-hole punch. The best type is that which works by turning a take-up screw with a wrench.

Square or rectangular holes may be cut out by making a row of small holes as previously described, but is more easily done by drilling a $\frac{1}{2}$ -inch hole inside each corner, as illustrated in Fig. 2002, and using these holes for starting and turning the hacksaw. The socket-hole punch also may be of considerable assistance in cutting out large rectangular openings.

The burrs or rough edges which usually result after drilling or cutting holes may be removed with a file, or sometimes more conveniently with a sharp knife or chisel. It is a good idea to keep an old wood chisel sharpened and available for this purpose.

Cutting Threads

Brass rod may be threaded, or the damaged threads of a screw repaired, by the use of *dies*. Holes of suitable size (see drill chart) may be threaded for screws by means of *taps*. Taps and dies are obtainable in all standard machine-screw sizes. A set usually consists of taps and dies for 4-36, 6-32, 8-32, 10-32 and 14-20 sizes, with a holder suitable for use with either tap or die. The die may be started easily by first filing a sharp taper or bevel on the end of the rod. In tapping a hole, extreme care should be used to prevent breaking the tap. The tap should be kept at right angles to the surface of the material, and rotation should be reversed a revolution or two whenever the tap begins to turn hard. With care, holes can be tapped rapidly by clamping the tap in the chuck of the hand drill and using slow speed. Machine oil applied to the tap usually makes cutting easier and sticking less troublesome.

Cutting and Bending Sheet Metal

If a sheet of metal is too large to be cut conveniently with a hacksaw, it may be marked with scratches as deep as possible along the line of the cut on both sides of the sheet and then clamped in a vise and worked back and forth until the sheet breaks at the line. Do not carry the bending so far that the break

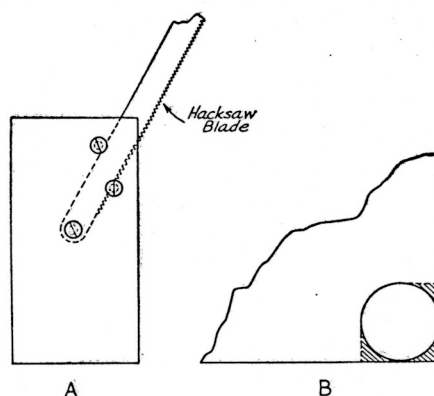


Fig. 2002 — To cut rectangular holes in a chassis, corner holes may be filed out as shown in the shaded portion of B, making it possible to start the hacksaw blade along the cutting line. A shows how a single-ended handle may be constructed for a hacksaw blade.

begins to weaken; otherwise the edge of the sheet may become bent. A pair of iron bars or pieces of heavy angle stock, as long or longer than the width of the sheet, to hold it in the vise will make the job easier. C-clamps may be used to keep the bars from spreading at the ends. The rough edges may be smoothed up with a file or by placing a large piece of emery cloth or sandpaper on a flat surface and running the edge of the metal back and forth over the sheet.

Bends may be made similarly. The sheet should be scratched on both sides, but not so deeply as to cause it to break.

☞ Cleaning and Finishing Metal

Parts made of aluminum can be cleaned up and given a satin finish, after all holes have been drilled, by placing them in a solution of lye for one-half to three-quarters of an hour. Three or four tablespoonfuls of lye should be used to each gallon of water. If more than one piece is treated in the same bath, each piece should be separated from the others so as to expose all surfaces to the solution. Overlapping of pieces may result in spots or stains.

☞ Crackle Finish

Wood or metal parts can be given a crackle finish by applying one coat of clear Duco or Tri-Seal and allowing it to dry over night. A coat of Kem-Art Metal Finish is then sprayed or applied thickly with a brush, taking care that the brush marks do not show. This should be allowed to dry for two or three hours and the part should then be baked in the kitchen oven at 225° for one and one-half hours. This will produce a regular commercial job. This finish, which comes in several different colors, is produced by the Sherwin-Williams Paint Co., and should be obtainable through any dealer handling Sherwin-Williams products.

☞ Hook-Up Wire

A popular type of wire for receivers and low-power transmitters is that known as "push-back" wire. It comes in sizes No. 16, 18, 20, etc., which is sufficiently large for all power circuits except filament. The insulating covering, which is sufficient for circuits where voltages do not exceed 400 or 500, can be pushed back a few inches at the end, making

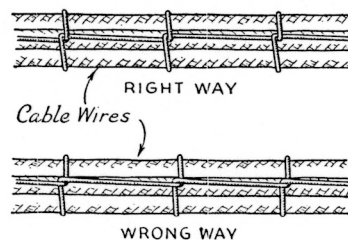


Fig. 2003 — Right and wrong methods of lacing cable. With the right way the leading line is pinched under each turn and will not loosen if a break occurs in the lacing.

cutting of the insulation unnecessary when making a connection. Filament wiring should be done with sufficiently large conductors to carry the required current without appreciable voltage drop (see Copper Wire Table, Chapter Twenty-One). Rubber-covered house-wire sizes No. 14 to No. 10 are suitable for heavy-current transmitting tubes, while No. 18 to No. 14 flexible wire is satisfactory for receivers and low-drain transmitting tubes where the total length of the leads is not excessive.

Stiff bare wire, sometimes called *bus wire* or *bus bar*, is most favored for the high r.f.-potential wiring of transmitters and, where practicable, in receivers. It comes in sizes No. 14 and No. 12 and is usually tin-dipped. Soft-drawn antenna wire also may be used. Kinks or bends can be removed by stretching 10 or 15 feet of the wire and then cutting it into small usable lengths.

The insulation covering power wiring which is to carry high transmitter voltages should be appropriate for the voltage involved. Wire with rubber and varnished cambric covering, similar to ignition cable, is available from radio parts dealers. The smaller sizes have sufficient insulation to be safe at 1000 to 1500 volts, while the more heavily insulated types should be used for voltages above 1500.

☞ Wiring Transmitters and Receivers

It is usually advisable to do the power-supply wiring first. The leads should be bunched together as much as possible and kept down close to the surface of the chassis. The lacing of power wiring in cable form not only improves its appearance but also strengthens the wiring. Fig. 2003 shows the correct way of lacing cabled wires. When done correctly the leading line is held tightly pinched in place after tension has been removed, and therefore does not loosen readily. When the wrong method is used the turns will loosen up as soon as tension is removed.

Chassis holes for wires should be lined with *rubber grommets* which fit the hole, to prevent chafing of the insulation. In cases where power-supply leads have several branches, it is often convenient to use fibre *terminal strips* as anchorages. These strips also form handy mountings for wire-terminal resistors, etc. When any particular unit is provided with a nut or thumb-screw terminal, soldering-lug wire terminals to fit are useful.

High-potential r.f. wiring should be well spaced from the chassis or other grounded metal surfaces and should be run as directly as possible between the points to be connected, without fancy bends. When wiring balanced or push-pull circuits, care should be taken to make the r.f. wiring on each side of the circuit as symmetrical as possible. Where it is necessary to pass r.f. wiring through the chassis, either a *feed-through* insulator of low-loss material should be used or the hole in the chassis should be of sufficient size to provide plenty of

air space around the wire. Large-diameter rubber grommets can be used to prevent accidental short-circuits to the chassis.

By-pass condensers should be connected directly to the point to be by-passed and grounded immediately at the nearest available mounting screw, making certain that the screw makes good electrical contact with the chassis. Care should be taken to connect the marked side of tubular paper by-pass condensers to ground. Blocking and coupling condensers should be well spaced from the chassis.

High-voltage wiring should have exposed points kept at a minimum and those which cannot be avoided rendered as inaccessible as possible to accidental contact.

❏ Soldering

The secret of good soldering is in allowing time for the *joint*, as well as the solder, to attain sufficient temperature. Enough heat should be applied so that the solder will melt when it comes in contact with the wires being joined, without touching the solder to the iron.

Wartime solder, which has a much smaller ratio of tin to lead, requires considerably more heat, and it becomes especially important to keep the iron clean at all times. More care must be exercised in making the joint because the new solder does not flow as readily, and also has a tendency to crystallize.

Soldering paste, if of the non-corroding type, is extremely helpful when used correctly. In general, it should not be used for radio work except when necessary. The joint should first be warmed slightly and the soldering paste applied with a piece of wire. Only the bit of paste which melts from the warmth of the joint should be used. If the soldering iron is clean it will be possible with one hand to pick up a drop of solder on the tip of the iron which can be applied to the joint, while the other hand is used to hold the connecting wires together. The use of excessive soldering paste causes the paste to spread over the surface of adjacent insulation, causing leakage or breakdown of the insulation. Except where absolutely necessary, solder should never be depended upon for the mechanical strength of the joint; the wire should be wrapped around the terminals or clamped with soldering terminals.

Do not attempt to make ground connections to a cadmium-plated chassis by soldering to the surface of the chassis, since the plating may be loosened by the heat and later fall off, breaking the connection. Drill a hole in the chassis and solder the wire in the hole.

❏ Construction Notes

Lockwashers should be used under nuts to prevent loosening with use, particularly when mounting tube sockets or plug-in coil receptacles subject to frequent strain.

If a control shaft must be extended or insulated, a flexible shaft coupling with adequate insulation should be used. Satisfactory support

for the shaft extension can be provided by means of a *metal* panel bearing made for the purpose. Never use panel bearings of the non-metal type unless the condenser shaft is grounded. *The metal bearing should be connected to the chassis with a wire or grounding strip.* This prevents any possible danger of shock.

The standard way of mounting toggle switches is with the switch "On" when the lever is in the upward position.

❏ Coil Winding

Dimensions for coils for the various units described in the constructional chapters are given under the circuit diagrams. Where no wire size is given, the power is sufficiently low to permit use of any available size within reason.

Unless a close-wound winding is definitely specified, the number of turns indicated should be spaced out to fill the specified length on the form. The length should be marked on the form and holes drilled opposite the pins to which the ends of the winding are to connect. Scrape one end of the wire and pass it through the lower hole in the form to the pin to which the bottom end of the winding is to connect, and solder this end fast. Unroll a length of wire approximately sufficient for the winding, and clamp the spool in a vise so it will not turn. The wire should be pulled out straight and the winding started by turning the form in the hands and walking toward the vise. A fair tension should be kept on the wire at all times. The spacing can be judged by eye. If, as the winding progresses, it becomes evident that the spacing is going to be incorrect to fill the required length, the winding can be started over again with a different spacing. If the spacing is only slightly off, the winding may be finished, the top end fastened, and the spacing corrected by pushing each turn. When complete, the turns should be fastened in place with coil cement. After a little practice, the job of determining the correct spacing will not be difficult.

Sometimes it is necessary to adjust the number of turns on a coil experimentally. The easiest way to do this is to bring a wire up from one of the pins, extending it through a hole in the form for a half-inch or so. The end of the winding may then be soldered to this extension rather than to the pin itself, and the nuisance of repeatedly fishing the wire through the pin avoided until the correct size of the winding has been determined.

❏ Coil Cement

Duco cement, obtainable universally at hardware, stationery or 5-and-10-cent stores, is satisfactory for fastening coil turns. For small coils, a better-looking job will result if it is thinned out with acetone (amyl acetate), sometimes referred to as banana oil. If desired, the solution may be made thin enough to permit application with a brush.

Special low-loss coil "dopes" are available, including some with a polystyrene base.

Tube Characteristics and Miscellaneous Data

THIS chapter contains a compilation of miscellaneous data useful to the practising radio amateur. The first part contains reference information intended to illustrate and supplement the basic material in the remainder of this *Handbook*. The larger part of the chapter is devoted to data on different types of receiving and transmitting tubes.

Inductance and Capacity

Inductance (L)—The formula for computing the inductance of air-core coils is:

$$L = \frac{0.2 a^2 n^2}{3a + 9b + 10c} \mu\text{h.}$$

where a is the mean diameter of the coil in inches, b is the length of the winding in inches, c is the radial depth of the winding in inches, and n is the number of turns. The quantity c may be neglected if the coil is a single-layer solenoid.

For example, assume a coil having 35 turns of No. 30 d.s.c. wire on a form 1.5 inches in diameter. Consulting the wire table (page 427), 35 turns of No. 30 d.s.c. will occupy 0.5 inch. Therefore, $a = 1.5$, $b = 0.5$, $n = 35$, and

$$L = \frac{0.2 \times (1.5)^2 \times (35)^2}{(3 \times 1.5) + (9 \times 0.5)} = 61.25 \mu\text{h.}$$

To calculate the number of turns of a single-layer coil for a required value of inductance:

$$N = \sqrt{\frac{3a + 9b}{0.2a^2} \times L}$$

More rapid and convenient calculations in designing coils can be made with the ARRL *Lightning Radio Calculator* (Type A).

Condenser capacity (C)—The formula for determining the capacitance of a condenser is:

$$C = 0.2235 \frac{KA}{d} (n - 1) \mu\text{fd.}$$

where A is the area of one side of one plate in square inches, n is the total number of plates, d is the separation between plates in inches, and K is the dielectric constant ($= 1$ for air; see the table on page 423 for values for other materials).

The dielectric constant is the ratio of the capacitance of a condenser with a given dielectric to its capacitance with air dielectric.

Linear Circuits

At very-high and ultrahigh frequencies transmission lines are used as linear resonant circuits. The following formulas cover the design of such circuits. All dimensions are in inches.

Characteristic impedance—The characteristic or surge impedance, Z_o , of various types of transmission lines may be computed as follows:

Single conductor to perfect ground:

$$Z_o = 138 \log \frac{2D}{a}$$

where D is the height of the conductor above ground and a is the radius of the conductor.

Concentric or coaxial conductor:

$$Z_o = \frac{138}{\sqrt{K}} \log \frac{b}{a}$$

where b is the *inside* radius of the outer conductor, a is the *outside* radius of the inner conductor and K is the dielectric constant ($= 1$ for air; see table for values for other materials).

When the dielectric consists of spaced insulating washers or beads with air between, a corrected value for K (K') must be used:

$$K' = \frac{K - 1}{s} w$$

where K is the dielectric constant of the spacer material, s is the distance between adjacent spacers, and w is the width of one spacer.

For concentric lines with square or trough-type outer conductors, the value for b is taken as the height of one side $\times 1.079$.

Parallel conductors:

$$Z_o = 276 \log \frac{D}{a}$$

where D is the center-to-center spacing between conductors and a is the radius of the conductors.

Parallel conductors in a concentric shield:

$$Z_o = \frac{276}{\sqrt{K}} \log \left[\frac{D}{a} \times \frac{1 - \left(\frac{D}{2b}\right)^2}{1 + \left(\frac{D}{2b}\right)^2} \right]$$

where K , D , b and a are the same as above.