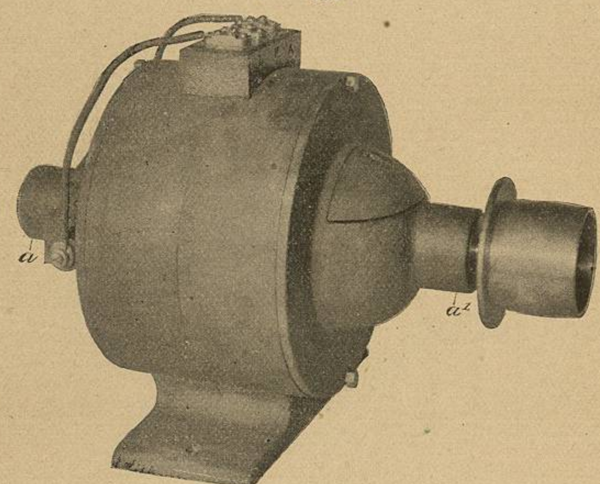
CHAPTER XIX.

A QUARTER-HORSE POWER ELECTRIC MOTOR.

The electric motor described on page 497 and the following pages was designed to be made from ordinary materials without the necessity of employing fine tools or machinery in its construction. It is operated by a current from the battery, everything connected with it being within the reach of any amateur. In this chapter an entirely different

Fig. 497



Quarter-Horse Power Electric Motor.

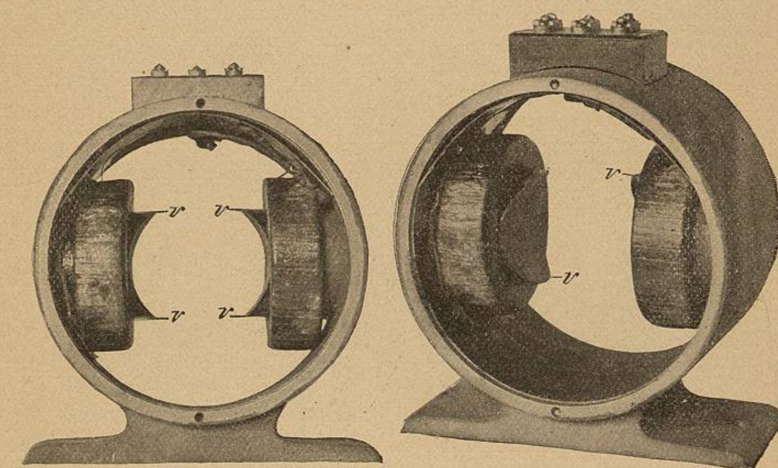
motor (Fig. 497) is shown and described, in which the best obtainable materials are used, and in the construction of which considerable mechanical skill is required and good tools are a necessity.

This motor was designed and built especially for the writer by Mr. W. S. Bishop for this edition of "Experimental Science," with the intention of giving the reader full particulars regarding the construction of a complete modern quarter-horse power self-regulating electric motor for use on a direct-current 110-volt circuit.

This motor is well proportioned, so that by enlarging or reducing it in proportion to sectional areas, a motor smaller or larger than the one illustrated may be constructed.

The motor is of the inclosed type, the field magnet forming a drum or cylindrical casing, with inwardly projecting pole pieces on which are placed the coils of the field magnet (Fig. 497*a*). The heads support self-oiling journals, *a a*[1] (Fig. 497) which receive the shaft of the armature, which latter revolves between the poles. The heads (Fig. 497*b*) are provided with removable sections for convenience

Fig. 497*a*

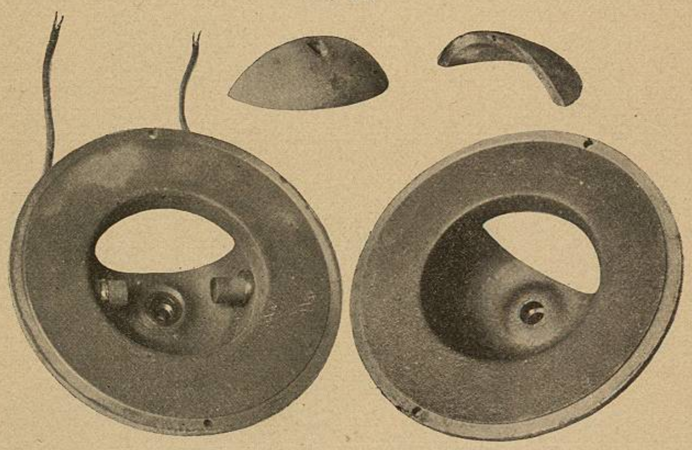


Field Magnet with Heads and Armature Removed.

in examining the interior of the field magnet. The commutator brushes consist of spring-pressed carbon rods inserted in the insulated brass sockets placed in horizontal holes bored in opposite sides of the head near one of the journals. The commutator revolves between and in contact with these carbon brushes. The electrical connections are made at the top of the casing, as will be presently described.

The steel armature shaft, which is supported by the self-oiling bearings in the heads, has a uniform diameter of $\frac{5}{8}$ inch, and is 16 inches long. On this shaft is placed a cast iron sleeve $3\frac{1}{4}$ inches long and 1 inch in outside diameter, (Fig. 498), with a head $2\frac{1}{8}$ inches in diameter and $\frac{3}{16}$ inch thick formed on one end, and a wrought iron nut of the same size on the other end. The sleeve is secured by a key. On the sleeve between the head and nut are mounted the disks of which the armature core is formed. The end ones are $\frac{1}{16}$ inch thick; the intermediate ones, No. 25, all are of soft sheet steel. The disks are varnished with thin shellac and dried before they are placed on the sleeve. These disks each have 18 notches, each of which is $\frac{3}{8}$ inch wide

FIG. 497*b*



The Heads of the Field Magnet.

at the periphery, $\frac{1}{8}$ inch wide at the bottom and $\frac{3}{4}$ inch deep. These notches, when the disks are placed together, form grooves for receiving the armature winding. The grooves are lined with strips of leatherboard which completely cover the edges of the disks. A washer of vulcanized fiber $\frac{1}{32}$ inch thick is placed at each end, covering the end disks, and having notches of the same size as those in the steel disks and holes large enough to admit the nut and flange.

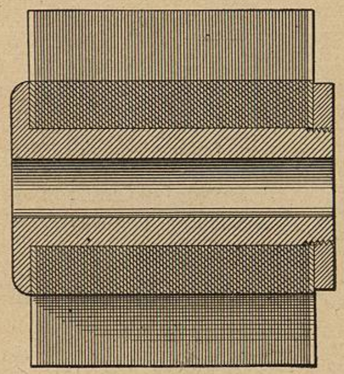
The nut and flange are each insulated by a washer of canvas provided with a number of radial slits to enable

them to form down over the edges of the flange and nut. These canvas washers are coated with shellac varnish.

Tubes of vulcanized fiber are placed on each end of the armature shaft adjoining the cast iron sleeve, so that no electrical connection can be made by the winding with the shaft. Every portion of the steel of the armature is thus protected, so that it cannot come into electrical contact with the winding. All of the insulating material is held in place by thick shellac varnish, which is allowed to dry thoroughly before the winding is done.

The armature is wound with No. 22 (A. W. G.) single

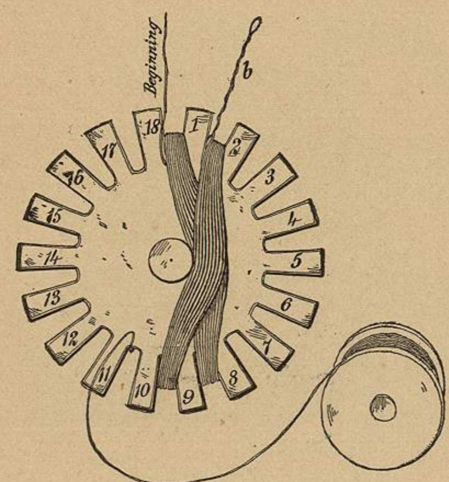
FIG. 498.



Armature Core, Half Size.

silk-covered copper wire. There are eighteen coils on the armature, with fifty-eight convolutions in each coil. The winding is done while the armature shaft is supported on lathe centers. To begin, 3 inches of wire are left projecting from the commutator end of the armature, as shown in Fig. 498*a*, and to avoid mistakes, the armature groove in which the beginning of the winding is made is marked 18-1 on opposite sides. Nine grooves are counted off and 8 is marked on one side of the ninth groove and 9 on the other side. The wire is then carried along in the groove 18-1 to the back end of the armature, thence over the end and past the shaft to the groove 8-9; along this groove to the commutator end of the armature, past the shaft to groove 18-1, along this groove to the rear end of the armature, and so on until grooves 18-1 and 8-9 contain fifty-eight turns; then carry the wire to groove 9-10, and back across the commutator end of the armature to groove 1-2, when a loop of about 4 inches long is formed outside of the groove, and the winding is continued in groove 9-10 and groove 1-2 as before, filling in fifty-eight turns, and so on until the grooves are half filled and the winding is one-half way around the armature; but

Fig. 498a.



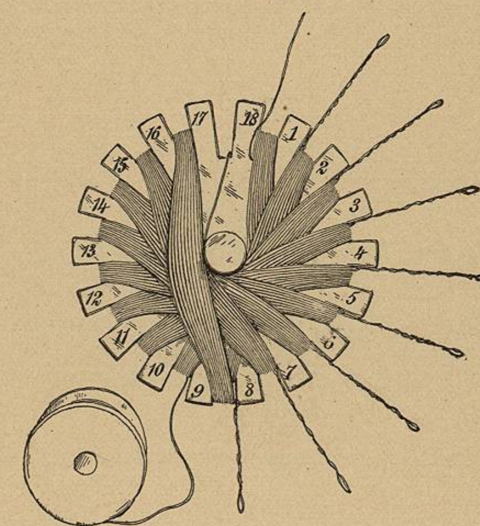
Beginning of the Winding.

each time a new coil is started the previous one must be protected by small pieces of oiled silk applied to the ends of the armature where the wires cross. After the coils are one-half on, i. e., after the winding has been carried around to the point of starting, the looped and twisted ends designed for commutator connections are thoroughly protected with tape close up to the coils, and the winding is continued the same way as before, winding fifty-eight turns of wire on top of the wire first wound, until every groove is filled, and the loop is brought out of every space, when

these loops are protected by tape, as already described, and the commutator is placed on the shaft. The doubled and twisted ends are cut off at the extreme end of the loop for attachment to the commutator bars.

The commutator (Fig. 498*e*) is a vital part of the motor, needing great care in its construction. It has a hub or sleeve, *b*, $1\frac{1}{2}$ inches long, provided with an undercut collar, *c*, formed on its inner end, and is provided with a removable collar, *d*, having an undercut portion, *c'*, corresponding

Fig. 498c.

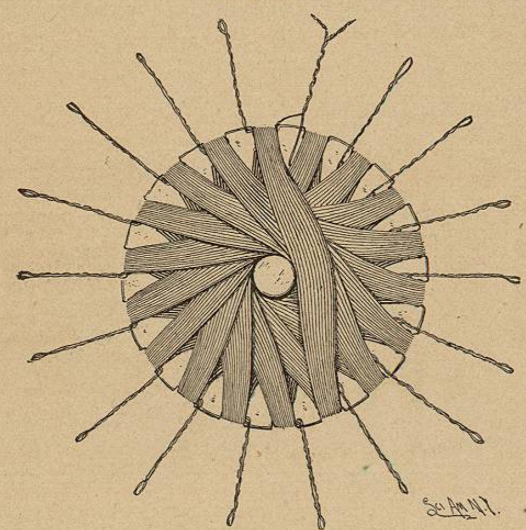


Winding the Last Coil of the First Series.

to the undercut flange, *c*, but oppositely arranged. Between these undercut portions are clamped the commutator bars, *e*. The latter are made of cast phosphor-bronze, when only a few are required. These are milled on the ends and inner side, the outside being turned off after the commutator is assembled.

Another way to make the commutator is to cast a cylinder of phosphor-bronze, having the cross section shown in Fig. 498*e*; afterward sawing the cylinder up into eighteen bars as shown. Each bar has a short, slotted arm extending in a radial direction for receiving a pair of terminals of the armature coil. The commutator sleeve or hub, *b*, is provided with a wrapping, *f*, and a washer, *g*, of mica for thoroughly insulating the bars from the sleeve, and with a mica disk, *h*, for insulating them from the collar, *d*. This collar is held in place by four screws passing through it into the sleeve, *b*. To economize space the inner end of the sleeve, *b*, is chambered, as shown. The commutator is prevented from turning on the shaft by a

FIG. 498*d*.



The Finished Winding.

lug pin, *i*, which is inserted in the shaft, and is received in a short slot, *j*, in the sleeve, *b*.

The commutator is $2\frac{7}{16}$ inches in diameter, the bars are 1 inch long, and $\frac{7}{16}$ wide on the outer face. They are separated evenly by strips of mica, which are turned off when the commutator is turned. The dimensions can be obtained from the engraving, which is one-half size.

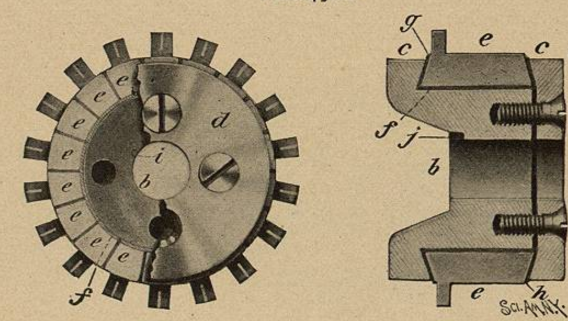
The looped ends of the armature coils are all carried to one side to the fourth commutator bar, and cleaned off and inserted in the slots of the arms projecting from the com-

mutator bars, the wires being soldered in the slots. This arrangement of the wires admits of placing the carbon commutator brushes in a horizontal position, which is desirable.

The terminals of the armature winding are all thoroughly separated by pieces of oiled silk. They are wrapped with stout twine to resist centrifugal force and are varnished with shellac.

In each slot of the armature is placed a strip of leatherboard to cover the coil, and in peripheral grooves turned at three points in the length of the armature, are placed windings of No. 18 piano wire, which are carefully soldered

FIG. 498*e*.



Sectional Views of the Commutator.

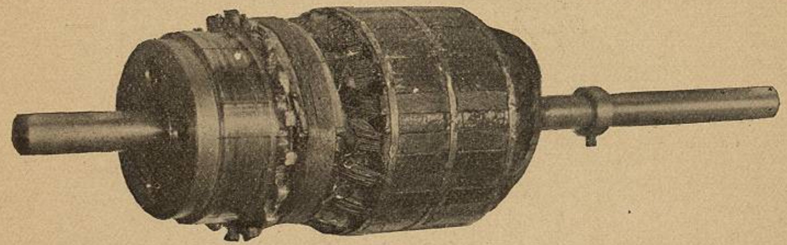
(Fig. 499). These windings prevent the bursting of the armature by centrifugal force. The winding and insulation of the armature is now provided with two or three coats of shellac varnish to exclude moisture and bind the wires and insulators.

The armature is now carefully balanced by adding solder to the peripheral bands, or by increasing the solder on the arms of the commutator bars. The armature is tested by rolling it on parallel bars arranged in a perfectly horizontal plane.

The field magnet, which has internal poles, *v*, is now bored to receive the armature and is faced off and bored to receive the heads. The latter are accurately fitted, so that each may be retained in place by two tap bolts as shown. Accuracy of position is secured by facing the inner side of the head and providing it with a shoulder which fits the finished edge of the field magnet. While the head is still in position in the lathe the support for the journal box is bored to insure proper alignment.

The journal boxes, *aa*[1] (Fig. 499*a*), each consist of a bronze sleeve bored internally to fit the shaft and turned off externally in two diameters, one to fit the hub of the magnet head and the other to make room for the oil chamber, *k*, which is further enlarged by the chambering out of the hub. The journal box is provided with an annular groove, *m*, to receive the oil from the end of the shaft, and a small duct, *n*, conveys the oil back to the reservoir. The journal outside

Fig. 499



The Finished Armature.

of the groove, *m*, is counter-bored to prevent it from coming into contact with the shaft.

A slot is cut across the upper portion of the journal box to loosely admit the ring, *l*, which rests upon the shaft and is revolved by frictional contact. The ring, *l*, carries up sufficient oil to keep the journal lubricated. The surplus oil falls from the inner end of the journal box directly into the oil reservoir. Collars are secured to the shaft at each end adjoining the journal boxes. The armature shaft is thus mounted so that the armature revolves within one-thirty-second inch of the polar extremities of the field magnet.

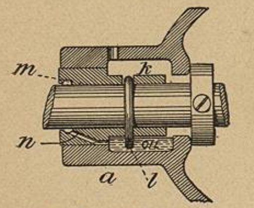
The commutator brushes, A (Fig. 499*b*), which form the electrical contacts with the commutators, each consist of a brass tube, *q*, having a thick head for receiving a binding

screw, *r*, for holding the lead wire, *s*. In the brass tube is placed a spiral spring, *t*, which presses the cylindrical carbon rod, *u*, forward into contact with the commutator cylinder. Each field magnet pole, *v*, is furnished with a coil, which is wound on a wooden form between two wooden collars on a strip of vulcanized fiber one-sixteenth inch thick wrapped around the form. After winding each coil is wound with adhesive tape and varnished with shellac. There is a total of $3\frac{3}{4}$ pounds of No. 28 single cotton-covered wire in the coils.

The wooden form for these coils should be a little larger than the magnet pole to insure the fitting of the magnet coils to the poles.

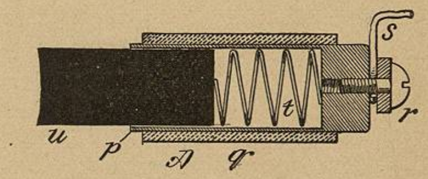
The coils are both wound in the same direction and connected in series, the outside ends being connected together,

Fig. 499*a*.



The Journal Box.

Fig. 499*b*.

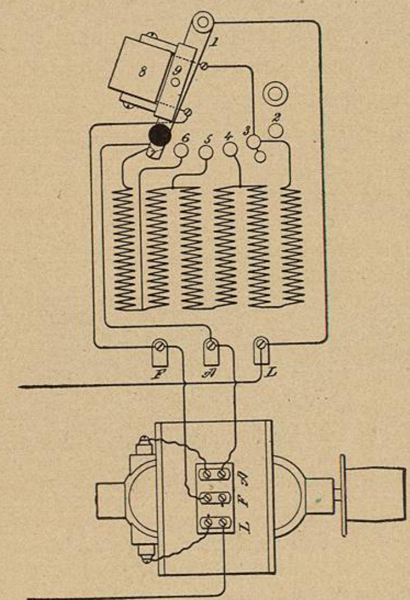


The Commutator Brush.

while the inner ends are connected one with the binding post, L, and the other with the binding post, F, both mounted on the block secured to the top of the field magnet. The binding post, L, is also connected with one of the commutator brushes, and the binding post, A, is connected with the commutator brush, but with no other part of the motor.

A rheostat or starting box is required to start the motor with safety. A diagram of the connections is given in Fig. 500, which is a plan view of the motor and a diagrammatic view of the rheostat. In this view the binding posts, F, A, are shown, the binding post, L, being connected with the line and one of the commutator brushes; the binding post, A, being connected with the other commutator brush and with the middle binding post of the rheostat. The binding post, F, of the rheostat is connected with the center binding post, F, of the motor, and the binding post, L, of the rheostat is connected with the line and also with the switch arm 1. The latter is capable of making a contact with either of the buttons 2, 3, 4, 5, 6, 7. The switch arm 1 has a spring which tends to throw it around into contact with the button 2, which has no electrical connection. The buttons 3 to 7 inclusive are connected with the resistance coils. When

FIG. 500



The Rheostat or Starting Box.

the arm 1 is brought into contact with the button 3, it throws all of the resistance into the armature circuit, and also throws the switch magnet, 8, into the field circuit, in which it remains with more or less resistance as long as the motor runs.

The switch arm cuts out the resistance gradually until the current is all on, when the armature, 9, carried by the arm, 1, is held by the magnet, 8. The parts remain in this position so long as the current passes. When the circuit is broken at any point, the magnet 8 releases the switch arm, and the spring causes it to fly back and break the circuit, thereby avoiding the danger of throwing a heavy current suddenly on the motor.

This motor will readily run on current taken from an ordinary lamp socket. It is so proportioned that the counter electro-motive force keeps the speed down to 1,600 revolutions per minute, and controls the current so as to render the motor uniform in its action.

By connecting the field magnet with the armature the machine may be run by power as a generator. When run at 1,850 revolutions per minute, it is able to supply three 16 candle power 110-volt lamps.

The following is a table of the dimensions of the motor:

Length of armature shaft	16	inches
Diameter " "	$\frac{5}{8}$	"
Diameter of the armature	$3\frac{3}{4}$	"
Diameter of the commutator	$2\frac{3}{8}$	"
Width of commutator	$1\frac{13}{16}$	"
Number of commutator bars, 18.		
Width of commutator bars	$\frac{5}{16}$	"
Length of bearing surface	$\frac{3}{4}$	"
Bore of the field magnet	$3\frac{13}{16}$	"
Outside diameter of field magnet drum	$8\frac{11}{16}$	"
Inside " " " "	$7\frac{7}{8}$	"
Width of " " " "	$5\frac{1}{4}$	"
Base	4 x $9\frac{1}{2}$	"
Height of drum above bottom of base	1	"
Diameter of inside of convex portion of head	4	"
Diameter of hole for receiving commutator brushes	1	"
Outside diameter of carbon brush holder	$\frac{13}{16}$	"
Carbon rod	$\frac{11}{16}$	"
Length of carbon	$1\frac{5}{8}$	"
Wire on the field magnet, $3\frac{3}{4}$ pounds of single cotton-covered, No. 28.		
Wire on armature, $2\frac{1}{4}$ pounds No. 22 single silk-covered.		
Normal speed of motor, 1,6co revolutions per minute.		

This little motor is a marvel of mechanical construction. It does not possess a single unnecessary part, and everything is plain, direct and simple.

TABLE OF TANGENTS.

Degrees.	Tangents.	Degrees.	Tangents.	Degrees.	Tangents.	Degrees.	Tangents.
1.	.0175	18.	.3249	35.	.7002	52.	1.279
1.5	.0262	18.5	.3346	35.5	.7133	52.5	1.303
2.	.0349	19.	.3443	36.	.7265	53.	1.327
2.5	.0437	19.5	.3541	36.5	.7400	53.5	1.351
3.	.0524	20.	.3640	37.	.7536	54.	1.376
3.5	.0612	20.5	.3739	37.5	.7673	54.5	1.401
4.	.0699	21.	.3839	38.	.7813	55.	1.428
4.5	.0787	21.5	.3939	38.5	.7954	55.5	1.455
5.	.0875	22.	.4040	39.	.8098	56.	1.482
5.5	.0963	22.5	.4142	39.5	.8243	56.5	1.510
6.	.1051	23.	.4245	40.	.8391	57.	1.539
6.5	.1139	23.5	.4348	40.5	.8541	57.5	1.569
7.	.1228	24.	.4452	41.	.8693	58.	1.600
7.5	.1317	24.5	.4557	41.5	.8847	58.5	1.631
8.	.1405	25.	.4663	42.	.9004	59.	1.664
8.5	.1495	25.5	.4770	42.5	.9163	59.5	1.697
9.	.1584	26.	.4877	43.	.9325	60.	1.732
9.5	.1673	26.5	.4986	43.5	.9490	60.5	1.767
10.	.1763	27.	.5095	44.	.9657	61.	1.804
10.5	.1853	27.5	.5206	44.5	.9827	61.5	1.841
11.	.1944	28.	.5317	45.	1.	62.	1.880
11.5	.2035	28.5	.5430	45.5	1.0176	62.5	1.921
12.	.2126	29.	.5543	46.	1.035	63.	1.962
12.5	.2217	29.5	.5658	46.5	1.053	63.5	2.005
13.	.2309	30.	.5774	47.	1.072	64.	2.050
13.5	.2401	30.5	.5890	47.5	1.091	64.5	2.096
14.	.2493	31.	.6009	48.	1.110	65.	2.144
14.5	.2586	31.5	.6128	48.5	1.130	65.5	2.194
15.	.2679	32.	.6249	49.	1.150	66.	2.246
15.5	.2773	32.5	.6371	49.5	1.170	66.5	2.299
16.	.2867	33.	.6494	50.	1.191	67.	2.355
16.5	.2962	33.5	.6619	50.5	1.213	67.5	2.414
17.	.3057	34.	.6745	51.	1.234	68.	2.475
17.5	.3153	34.5	.6873	51.5	1.257	68.5	2.538

TABLE OF TANGENTS—*Continued.*

Degrees.	Tangents.	Degrees.	Tangents.	Degrees.	Tangents.	Degrees.	Tangents
69.	2.605	74.5	3.605	80.	5.671	85.5	12.706
69.5	2.674	75.	3.732	80.5	5.975	86.	14.300
70.	2.747	75.5	3.866	81.	6.313	86.5	16.349
70.5	2.823	76.	4.010	81.5	6.691	87.	19.081
71.	2.904	76.5	4.165	82.	7.115	87.5	22.903
71.5	2.988	77.	4.331	82.5	7.595	88.	28.636
72.	3.077	77.5	4.510	83.	8.144	88.5	38.188
72.5	3.171	78.	4.704	83.5	8.776	89.	57.290
73.	3.270	78.5	4.915	84.	9.514	89.5	114.588
73.5	3.375	79.	5.144	84.5	10.385	90.	
74.	3.487	79.5	5.395	85.	11.430		