Aug. 30, 1949. E. C. PIERCE 2,480,671

VARIABLE INDUCTANCE DEVICE

Filed Aug. 10, 1946

3 Sheets-Sheet 1

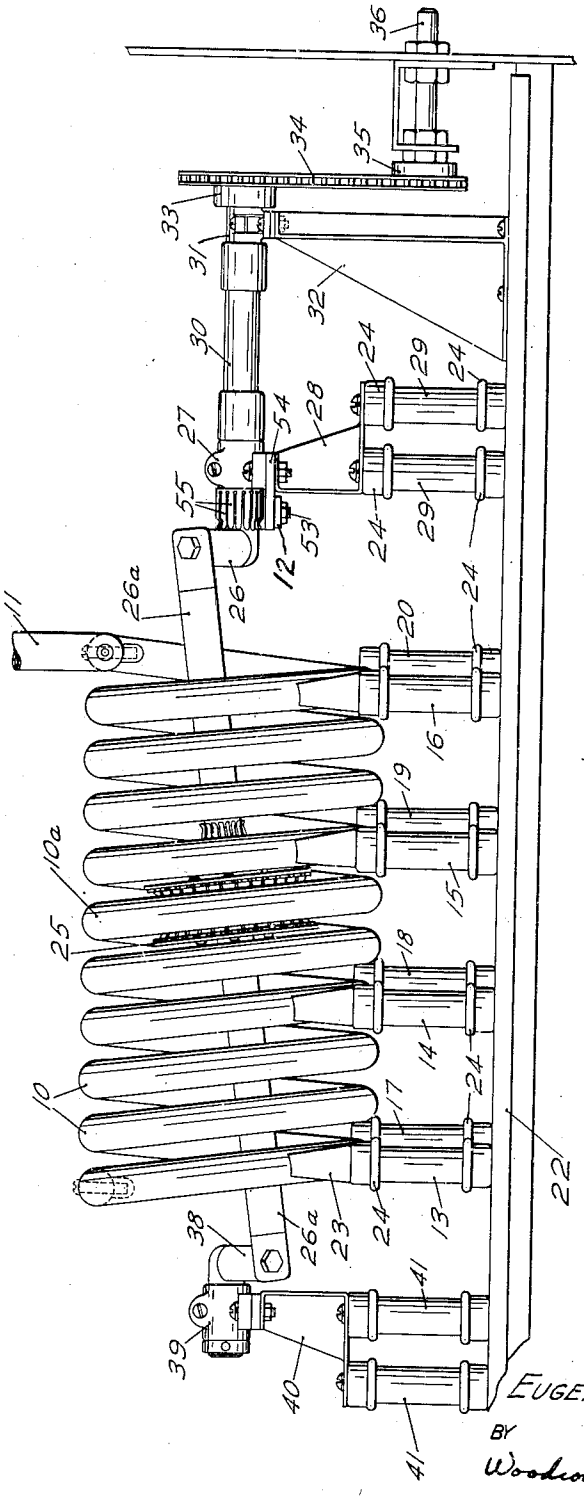


Fig. 1.

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Fig. 2.

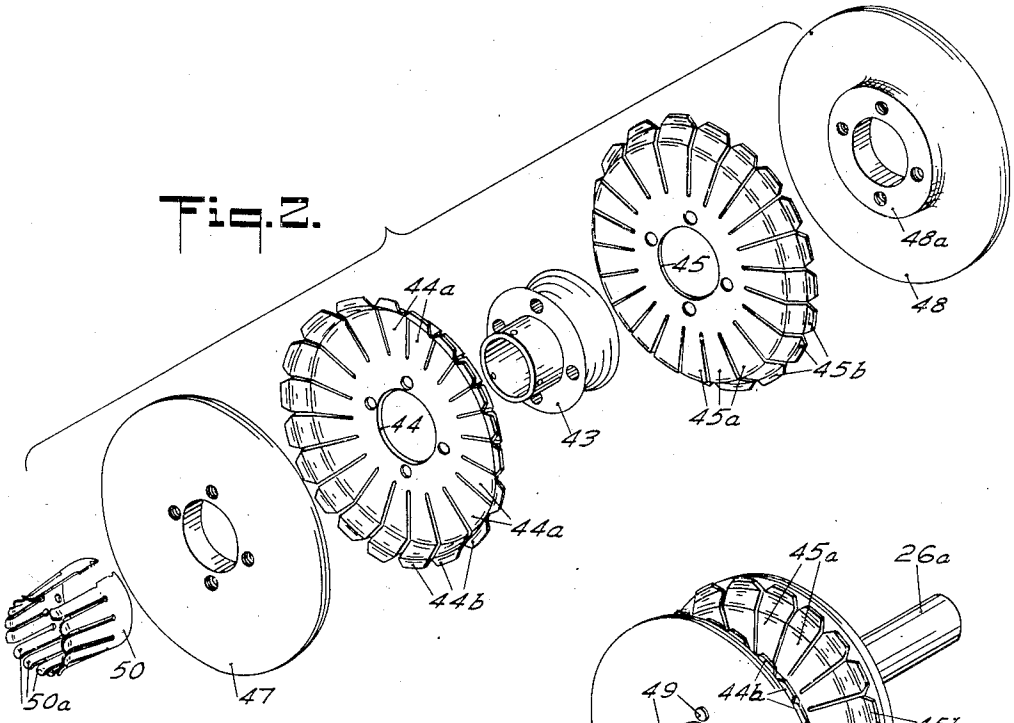


Fig. 3.

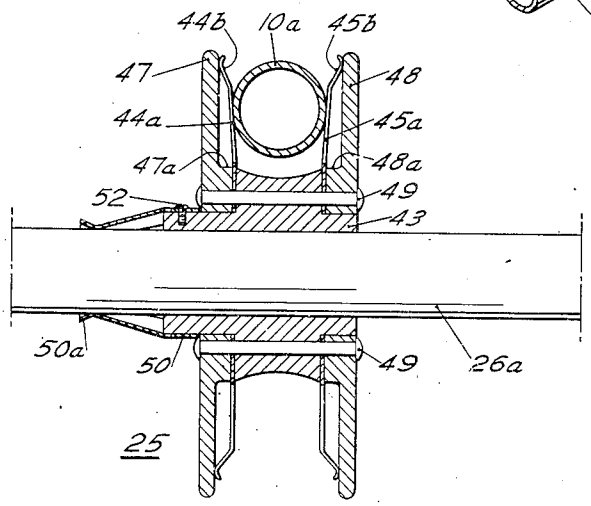


Fig. 4.

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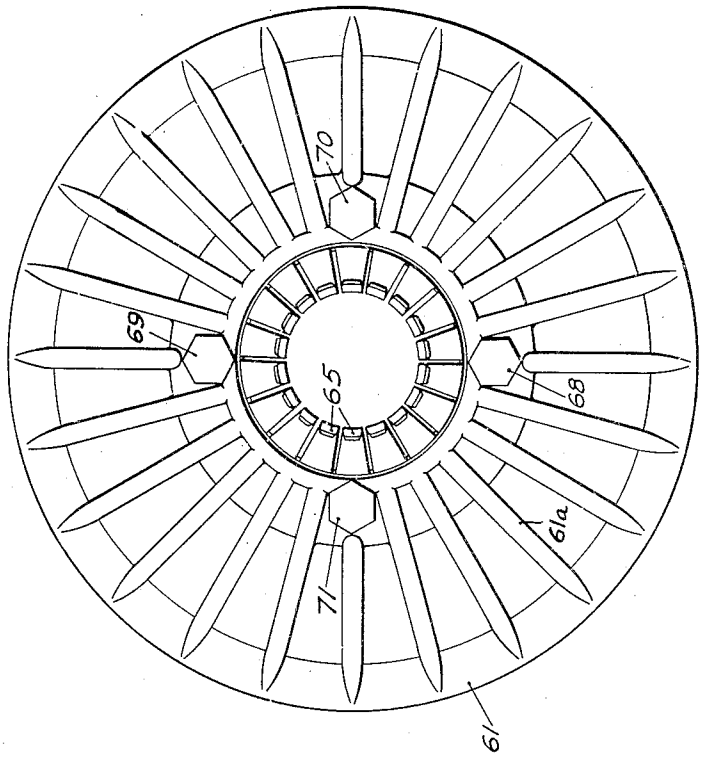


Fig. 6

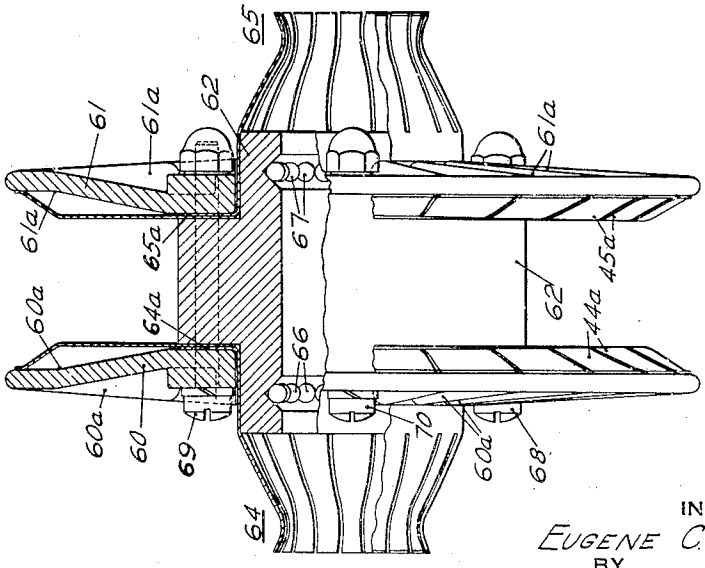


Fig. 5

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UNITED STATES PATENT OFFICE

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VARIABLE INDUCTANCE DEVICE

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11 Claims. (Cl. 171—242)

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This invention relates to variable inductance devices such as high-frequency high-power tuning coils and has for an object the provision of a coil of high electrical efficiency, of rugged mechanical design, and smoothly adjustable over a wide range of inductance values.

Heretofore, helical tuning coils have been proposed in which the turns of the coil have served as threads in order to advance a contact device lengthwise of the coils. In every tuning coil or variable inductance, there is some departure in the turns of the coil from a true helix. Accordingly, the movable contact member must provide not only for the deviation of the coil from a true helix but also there must be provision for the maintenance of a good electrical contact at all times. This is important from the standpoint of preventing undue heating. If a poor electrical contact is present, arcing and burning effects may appear which may seriously injure or abrade the conductor and thereby render difficult or prevent subsequent adjustment or tuning of the coil. In the past, it has been proposed to bias rolling contacts outwardly against the inner surface of the coiled conductor to insure good electrical contact and also to provide for irregularities in the curvature of each turn. Such a roller provides a line contact and sometimes more nearly a point contact with consequent undue heating thereof under heavy load. When it is considered that the current carried by tuning coils in high-frequency heating apparatus may be of the order of 100 amperes, it will be understood why many arrangements of the prior art have not proven entirely satisfactory.

In carrying out the present invention in one form thereof, a variable inductance coil having a plurality of turns forming a helix is provided with a crank arm which has a straight portion which rotates in a circular path which is concentric with the coil. On the straight portion of the crank there is disposed a contact device which is slidable and rotatable with respect to said straight portion of the crank. This contact device consists of two side discs which extend radially outward from the straight portion of the crank arm to a point beyond the widest diameter of the cylindrical conductor which forms the turns of the coil, and preferably somewhat beyond the remote or outer side of the turn. The two discs form supports for a plurality of spring fingers arranged in a circular array around each disc. The fingers associated with each disc are anchored thereto adjacent the straight portion of the crank and extend outwardly of each disc in spaced relation

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with the inner surface thereof, each spring or contact finger terminating with an end portion bent toward the disc and slidably engaging it. Thus, the arrangement provides between the two discs a plurality of spring fingers which form a good wiping electrical engagement along opposite sides of the turn of the coil or helical conductor. The array of spring fingers on opposite sides of a turn form short divided paths for current flow and for flow of heat to the heat-dissipating discs. By mounting the straight portion of the crank at an angle to the axis of the coil, the discs and the spring fingers are disposed for rotation in a plane generally parallel with the pitch of the coil. The intermediate portion of the spring fingers is long enough to take care of all radial irregularities in the coil, and the resilience of the spring fingers not only insures good wiping electrical contact in a plurality of directions but also provides for any axial irregularities in the formation of the coil. Preferably, additional spring fingers secured to one or both of the discs or a hub therefor extend into resilient engagement with the straight portion of the crank.

Tuning coils constructed in accordance with the present invention have been found highly satisfactory under severe conditions of operation where the current has been in excess of 100 amperes, with a frequency above a million cycles per second, specifically 6.4 megacycles, and with relatively high radio-frequency voltages, of the order of from 7000 to 12,000 volts.

For a more detailed understanding of the invention and for further objects and advantages thereof, reference is to be had to the accompanying drawings in which:

Fig. 1 is a side elevation of a tuning coil embodying the invention;

Fig. 2 is an exploded perspective view of the essential parts of the contact assembly;

Fig. 3 is a perspective view of the contact device in its assembled form;

Fig. 4 is a sectional elevation of the contact device of Fig. 3;

Fig. 5 is a sectional elevation of a modified form of a contact device; and

Fig. 6 is a side elevation of the device of Fig. 5.

Referring to the drawings, the invention has been illustrated in one form as comprising a variable inductance coil 10 arranged to be connected in an electrical circuit by means of a conductor 11 and a terminal member 12. The coil 10 is wound in the form of a helix and it is supported by means of a plurality of insulators 13—16 on the front side thereof as viewed in Fig. 1,

and insulators 17—20 on the far side thereof. The lower metal cap of each insulator is suitably secured at the lower end to a base 22 and from the upper metal cap thereof has extending therefrom a lug 23, the upper end of which is brazed or otherwise rigidly secured to a narrow outer peripheral area of a selected turn of the coil. As shown, the metal caps may also support stress-relieving rings 24. Since the coil itself is constructed of relatively heavy tubing, preferably of copper or other material having a low electrical resistance, the coil may be relatively self-supporting; that is, the insulators need only be provided for approximately every third or fourth turn thereof.

In order to rotate a movable contact device 25 around the several turns of the coil, a crank 26 is provided having a straight portion 26a extending lengthwise of the coil for rotation in a generally circular path spaced from the axis of the coil. More specifically, the crank includes a straight portion in alignment with the axis of coil 10 and journaled in a bearing 27 carried by a bracket 28 mounted on insulators 29. Included in the drive for the crank is an insulator 30, a second bearing 31 mounted on a bracket 32, and a sprocket wheel 33. A sprocket chain 34 interconnects the wheel 33 and a driving sprocket 35 which is secured to a drive shaft 36. The shaft 36 may be driven by hand crank or, preferably, by a reversible motor, so that the crank 26 may be driven at will in either direction. The straight portion 26a of the crank is disposed at an angle with respect to the longitudinal axis of the coil, and at such an angle as to incline or tilt the contact device 25 to coincide with the pitch of the coil 10. Accordingly, the left-hand end of the straight portion 26a of the crank 26 is supported by an arm 38 carried by a bearing 39 mounted on a bracket 40 which is in turn supported by insulators 41. The arm 38 is not disposed in the same plane as the arm forming the crank 26, but is angularly displaced therefrom to cause the sraight portion 26a angularly to extend through the coil 10. This skewed crank-shaft arrangement serves important purposes which will be later described in detail.

The contact device 25, as best shown in Figs. 2–4, includes a hub 43 which is slidably and rotatably carried by the straight portion 26a of the crank. Though a plain bearing is satisfactory, anti-friction devices may be included between the hub and the straight portion 26a, if desired. There is secured to the hub 43 thin conducting members 44 and 45, each having a plurality of spring fingers 44a and 45a arranged in circular or radial array. The conducting members 44 and 45 are generally cup-shaped, or dish-shaped, by reason of the out-turned ends 44b and 45b thereof. They are preferably formed of beryllium-copper alloy. As best shown in Fig. 4, these out-turned ends 44b and 45b slidably press against a pair of discs 47 and 48 respectively provided with shoulders 47a and 48a directed toward the hub 43 and which are held in place by suitable means, such as rivets 49. Accordingly, there is provided along the discs 47 and 48 a relatively long straight area formed by the spring or contact fingers 44a and 45a. These fingers provide for a sliding and wiping engagement with the opposite sides of the turn 10a of the coil 10. The rounded out-turned ends 44b and 45b of these spring fingers slide along the discs 47 and 48 as a turn 10a of the coil 10 departs from a true helix. The initial or unflexed position of the spring or contact fingers 44a and 45a is substantially parallel with the discs 47 and 48, and the fingers 44a and 45a are spaced considerably closer together than a distance equal to the diameter of a turn 10a. Stated differently, with the contact device 25 in engagement with a turn 10a, the spring fingers 44a and 45a are pressed away from each other to form a good wiping electrical contact with the turn 10a. Accordingly, if there is axial deviation of a turn 10a from a true helix, the spring fingers on one side of the turn will be compressed to a slightly greater degree, while the spring fingers on the opposite side will still engage the opposite side of the coil. Should the radius of a turn change, the relatively long area of the spring fingers provides for such variation without change in the good electrical contact maintained with the turn.

To provide a good electrical connection between the hub 43 and the straight portion 26a, and to avoid possibility of arcing at the bearing surface, a more or less conical conducting member or sleeve 50 is provided, which conducting member is provided with a plurality of resilient contact fingers 50a which extend outwardly from the hub 43 into sliding contact engagement with the straight portion 26a of the crank. The conducting member or sleeve 50 may be secured to the hub 43 by any suitable means, such as a plurality of screws 52, Fig. 4.

By inclining the straight portion 26a of the crank 26, Fig. 1, with respect to the axis of the coil 10, the plane of the discs 47 and 48 is tilted or disposed at an angle equal to the pitch or inclination of the turns of the coil 10. Accordingly, a plurality of the contact fingers 44a and 45a of the contact device 25 (as many as five or more on each side of the coil) at all times grip a turn of the coil and yet they offer a minimum of mechanical opposition to a change in position thereof upon rotation of the crank 26 by means of the drive shaft 36. There is insured at all times a substantial area of contact in contrast with a line contact or a point contact on the inner surface of the helical conductor, which point contact has heretofore been present on many tuning coil devices. The effective contact area is also increased by locating the contact fingers 44a and 45a on both sides of a turn of the coil; the several spring fingers 44a and 45a, by reason of the bending or deflection thereof, tend partly to encircle the coil 10a and thus provide area contact, in contrast with line contact, therewith. For example, in a device where the conductor of the tuning coil 10 had a diameter of seven-eighths of an inch, there was attained, on the average, of the order of a half a square inch of contact surface between the spring fingers and a turn of the coil. Notwithstanding this relatively large contact area, the contact device 25 could be readily moved to any desired point on any turn of the coil. More specifically, as the drive shaft 36 is rotated to rotate the crank 26, the frictional engagement between the contact members or fingers 44a and 45a causes them to rotate with respect to a turn of the coil and with respect to the straight portion 26a of the crank 26. This rolling-wiping contact engagement is important to the present invention since it has proven to be a highly desirable feature. The rolling-wiping contact surface of the device 25 constantly changes during adjustment along a turn of the coil, and there is thereby assured a good, clean electrical contact of low resistance. The wiping and cleaning action on each contact finger occurs radially thereof as well as from side to side. The action is in all directions

over the surface of the contact fingers and with respect to the turn of the coil so that there is assured a good electrical and thermal engagement between the fingers and the turn of the coil. The skewed arrangement with the narrow contact discs permits a reduced spacing of the turns and thus better "Q" values may be obtained. By reducing the pitch, the frictional resistance is also decreased.

By connecting one end of the coil to the conductor 11, any number of turns of the coil 10, or any fraction of a turn, may be included in a circuit extending between the conductors 11 and the terminal member 12 which leads to the other conductor of the circuit. The terminal member 12 is fastened as by a screw 53 to a plate 54 which is electrically connected to a plurality of spring fingers 55 which resiliently form a wiping contact engagement with a conductor forming the bearing-supported part of the crank 26. Thus, if the contact device by suitable rotation of the drive shaft 36 is moved to the right-hand end of the coil as viewed in Fig. 1, it will be observed that the coil as a whole may be excluded from the circuit, there then being a substantial direct electrical path from the conductor 11 through the contact device 25, the straight portion 26*a*, the right-angle arm portion of the crank 26, through the resilient contacts or spring fingers 55, the plate 54, the terminal member 12, and to the other conductor, not shown. However, in Fig. 1, it will be observed approximately five turns of the coil are connected in the circuit between conductor 11 and the terminal member 12.

Though devices embodying the invention have satisfactorily carried loads upwardly of 100 amperes over substantial periods of time without damage, higher loads may of course be safely carried by increasing the size of the conductors and of the contact assembly 25. In comparison with other tuning coil arrangements, the present invention indicates that for a comparable size of conductors, there is attained a surprisingly large increase of current capacity, as much as seventy per cent. The heat-radiating capacity of the movable contact assembly is even greater, and more of the order of three hundred per cent of that in comparable devices of the prior art due to the increased current-carrying ability. The unusual increase in the heat-radiating capacity is due to a number of factors. For example, the multiplicity of spring fingers or contact members are spaced from the discs 47 and 48 to provide a maximum radiation area. There is little to interfere with thermal circulation of air around the contact fingers which assists in carrying away any heat which may develop. When heat does develop in the contact fingers, it readily flows through the multiple and relatively short heat-conducting paths to the discs 47 and 48 which provide additional and relatively large heat-dissipating surfaces for rapid dissipation thereof as by radiation.

Referring to Figs. 5 and 6, there is illustrated a modified form of the contact device, which may be taken as suggestive of other forms of the invention which may be made within the scope of the appended claims. For example, the two supporting members or discs 60 and 61 of aluminum have been designed so that the inner surfaces 60*a* and 61*a* slope outwardly from adjacent the hub 62 to provide the necessary clearances along the radial lengths of the respective contact fingers 44*a* and 45*a*. By having the two discs 60 and 61 flaring outwardly from the hub 62, room is provided for a plurality of heat-radiating and dissipating fins 60*a* and 61*a*, without increasing the overall axial dimension of the assembly including the discs and without reducing the space between each disc and the adjacent turn of the coil. These fins 60*a* and 61*a* are formed inwardly of each disc and, as shown in Fig. 5, the outer surfaces thereof are substantially in the plane of the discs. The fins are spaced one from the other and from the periphery of the discs toward the hub have gradually increasing areas. The contact fingers 44*a* and 45*a* are spaced substantially from the angularly disposed inner faces of the discs 60 and 61 so that ample room is provided for deflection of the fingers to take care of their wiping and cleaning engagement with the turn of the conductor and also to provide for deflection to take care of any variation in diameter of the conductor of the coil.

Further in accordance with Fig. 5, two circular arrays of contact fingers 64 and 65 are provided at the respective ends of the hub 62, these terminating at the hub 62 in out-turned flanges 64*a* and 65*a* which are disposed between a shoulder of the hub 62 and the discs 60 and 61. Since the conductors of contact fingers 44*a* and 64 (and 45*a* and 65) are in abutting and overlapping contact with each other, there is provided a direct electrical path from the conductor of the coil through the contact fingers 44*a* and 45*a* to the contact fingers 64 and 65 which complete the electrical connection to the crank arm. By providing the double array of contact fingers 64 and 65, a centering action is attained and the contact device as a whole may be relatively loosely mounted on the crank arm. This minimizes friction and allows for diametrical expansion as between the crank arm and the hub. There may also be provided the anti-friction devices which are shown to consist of a plurality of ball bearings 66 and 67 disposed in V-shaped raceways formed in the hub 62.

In both forms of the invention, the spring fingers which engage the crank, form a wiping and sliding engagement therewith which, it will be observed, is both a rotating engagement and a sliding engagement, thus insuring a maximum cleaning action and a minimum electrical resistance.

The assembly and disassembly of the contact device is readily accomplished by the removal of a few bolts, generally four, three of which, the bolts 68—70 appear in Fig. 5, and the other of which, the bolt 71 also appears in Fig. 6. These thru-bolts clamp all of the parts together and form the sole fastening means to provide a rugged assembly of the contact device.

While preferred embodiments of the invention have been fully described, it is to be understood that modifications may be made within the scope of the appended claims which set forth those features which distinguish it from other inventions and which are distinctly claimed as characterizing the present invention.

What is claimed is:

1. In a variable inductance coil having a plurality of turns forming a helix and a crank having a straight portion extending lengthwise of said coil and inclined with respect to the longitudinal axis of said coil for rotation in a circular path about said axis of said coil, the combination of contact means for said coil comprising two discs disposed on opposite sides of a turn of said coil and rotatably carried by said straight portion, and a plurality of spring fingers respectively

anchored to said discs adjacent said straight portion and in circular array extending outwardly toward the peripheries of said discs, the outer ends of said spring fingers being bent toward the discs to space the intermediate portions therefrom for resilient engagement with opposite sides of a turn of said coil, rotation of said crank producing relative rotation between said discs and spring fingers as a unit with respect to a turn of said coil and along said straight portion progressively to change the electrical connection from said crank to said coil with a minimum of mechanical effort.

2. In a variable inductance coil having a plurality of turns forming a helix and a crank having a straight portion angularly extending lengthwise of said coil for rotation in a circular path spaced from the axis of said coil, the combination of contact means for said coil comprising a hub rotatably and slidably mounted on said straight portion, a plurality of contact fingers extending from said hub into resilient contact engagement with said straight portion, a pair of discs disposed on opposite sides of said hub and extending outwardly therefrom into overlapping engagement with a turn of said coil, and a plurality of spring fingers respectively anchored to each of said discs and to said hub and in circular array extending outwardly from said hub toward the peripheries of said discs, the outer ends of said spring fingers being bent respectively toward their associated disc to space the intermediate portions therefrom for resilient wiping engagement with the opposite sides of a turn of said coil, rotation of said crank producing rotation of said circular array of spring fingers with respect to said turn of said coil to change the electrical connection along said turn and to change the contact fingers engaging the opposite sides of said turn.

3. In a variable inductance coil formed by a helical conductor, contact means therefor comprising discs spaced apart a distance greater than the outside diameter of the conductor of a turn of said coil, to circular arrays of resilient contact fingers respectively having their outer end-portions slidably engaging the peripheral portions of said discs and means for anchoring the inner end-portions of said arrays of contact fingers to provide intermediate portions disposed for resilient wiping contact engagement with a turn of said coil.

4. A continuously variable inductance comprising spaced turns of a conductor formed into a helix, a shaft spaced from and rotatable about the axis of said helix, contact structure rotatably and slidably mounted on said shaft comprising a pair of cup-shaped spring contact members spaced to press against opposite sides of said conductor and of diameter insuring their continued engagement with said sides of said conductor for all positions of said shaft and notwithstanding variations in diameter of said helix, and a pair of backing discs thermally, mechanically and electrically engaging said members throughout the outer peripheries thereof.

5. In a variable inductance coil having a plurality of turns of a conductor formed into a helix and a crank arm rotatable within said helix, the combination of a heat-radiating current-carrying contact means comprising two members, rotatable and slidable with respect to said crank arm, spaced apart a distance somewhat greater than the axial dimension of said conductor, said members providing a substantial area for dissipation of heat therefrom as by radiation, and a plurality of spring fingers carried adjacent corresponding ends thereof by said members, their opposite ends being bent towards and slidably engaging said members to provide resilient contact areas for engaging opposite sides of a turn of said coil, the spring fingers engaging a turn of said coil providing dual heat-conducting and current-carrying paths for flow of heat and current to said heat-dissipating members.

6. In a variable inductance coil having a plurality of turns of a conductor formed into a helix and a crank arm rotatable within said helix, the combination of a heat-radiating current-carrying contact means comprising two members, rotatable and slidable with respect to said crank arm, spaced apart a distance somewhat greater than the axial dimension of said conductor, said members having a plurality of heat-radiating fins providing a substantial area for dissipation of heat therefrom as by radiation, a plurality of spring fingers disposed in circular array between said members, and means supporting the inner portions of said fingers in heat-conductive relation with said members, the opposite outer ends of said spring fingers being bent towards and slidably engaging said members to provide intermediate resilient contact areas for engaging opposite sides of a turn of said coil, a plurality of said spring fingers simultaneously engaging a turn of said coil to provide dual and relatively short heat-conducting and current-carrying paths for flow of heat and current to said heat-radiating members.

7. A variable inductance comprising a conductor in the form of a helical coil of substantially uniform diameter, a crank arm having a straight elongated member spaced outwardly from the axis of said coil, extending longitudinally of said coil, and supported for rotation in a circular path generally concentric with said coil, a contact device carried by and rotatable relative to said member and longitudinally movable along said member while electrically connected thereto, said contact device having a plurality of resilient contact fingers disposed in circular array around said elongated member and extending radially outward therefrom for resilient engagement with a side of said conductor which faces toward one end of said coil to complete a low-resistance connection thereto and to propel said contact device in one direction, said fingers successively engaging said conductor as said contact device rotates relative to said elongated member of said crank arm and as the latter rotates relative to said coil, and structure carried by said contact device engaging the side of said conductor facing toward the other end of said coil for propelling said contact device along said elongated member in the other direction to follow the turns of said coil.

8. A variable inductance comprising a conductor in the form of a helical coil of substantially uniform diameter, a crank arm having a straight elongated member spaced outwardly from the axis of said coil, extending longitudinally of said coil, and supported for rotation in a circular path generally concentric with said coil, a contact device carried by and rotatable relative to said member and longitudinally movable along said member while electrically connected thereto, said contact device having a plurality of resilient contact fingers disposed in circular array around said elongated member and extending radially outward therefrom for resilient engagement with a side of said conductor which faces toward one

end of said coil to complete a low-resistance connection thereto and to propel said contact device in one direction, said fingers successively engaging said conductor as said contact device rotates relative to said crank arm member as the latter rotates relative to said coil, and a second circular array of contact fingers extending radially outward from said contact device for resilient engagement with the side of said conductor facing toward the other end of said coil to complete a low-resistance connection thereto and to propel said contact device in the other direction and to follow the turns of said coil.

9. In a variable inductance coil having a plurality of turns forming a helix and a crank having a straight portion extending lengthwise of said coil and inclined with respect to the longitudinal axis of said coil for rotation in a circular path about said axis of said coil, the combination of a contact device carried by said straight portion comprising two discs extending outwardly from said straight portion on opposite sides of a turn of said coil and rotatably carried by said straight portion, resilient cup-shaped contact members respectively between said discs and said opposite sides of said turn of said coil and each mechanically and electrically in engagement with one of said sides and with one of said discs, rotation of said crank producing relative rotation of said discs and said contact members progressively to bring different parts of said contact members into wiping engagement with said opposite sides of said turn of said coil as said relative rotation progressively moves said contact device along said turn of said coil.

10. In a variable inductance coil having a plurality of turns forming a helix and a crank having a straight portion angularly extending lengthwise of said coil for rotation in a circular path concentric with and spaced from the longitudinal axis of said coil, the combination of contact means for said coil comprising a hub rotatably and slidably mounted on said straight portion, a pair of discs supported from said hub and extending outwardly therefrom into overlapping relation with a turn of said coil, and a plurality of spring fingers disposed in circular arrays about said hub and respectively between said discs and the opposite sides of the turn of said coil for making electrical and thermal contact with said turn of said coil and with said discs, the outer ends of said spring fingers being bent respectively toward their associated discs to space the intermediate portions therefrom for resilient wiping engagement with the opposite sides of a turn of said coil, rotation of said crank producing rotation of said circular array of spring fingers with respect to said turn of said coil to change regions of thermal and electrical contact with said turn and to change the contact fingers engaging the opposite sides of said turn.

11. In a variable inductance coil formed by a helical conductor, contact means therefor comprising discs spaced apart a greater distance than the outside diameter of the conductor of a turn of said coil, two circular arrays of resilient contact fingers respectively having their outer end portions slidably engaging the peripheral portions of said discs, means for anchoring the inner end portions of said arrays of contact fingers to provide intermediate portions disposed for resilient wiping contact engagement with a turn of said coil, and means rotatably supporting said anchoring means for rotation of said arrays of contact fingers concurrently with circumferential movement thereof along said helical conductor from one position to another.

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