

[72] Inventor **Howard A. Boltz**
Saratoga, California
[21] Appl. No. **809,725**
[22] Filed **March 24, 1969**
[45] Patented **Sept. 8, 1970**
[73] Assignee **Lockheed Aircraft Corporation**
Burbank, California

[56]

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Primary Examiner—Gil Weidenfeld

Attorneys—Robert B. Kennedy and George C. Sullivan

[54] APPARATUS FOR REMOVING ELECTRICAL INSULATION

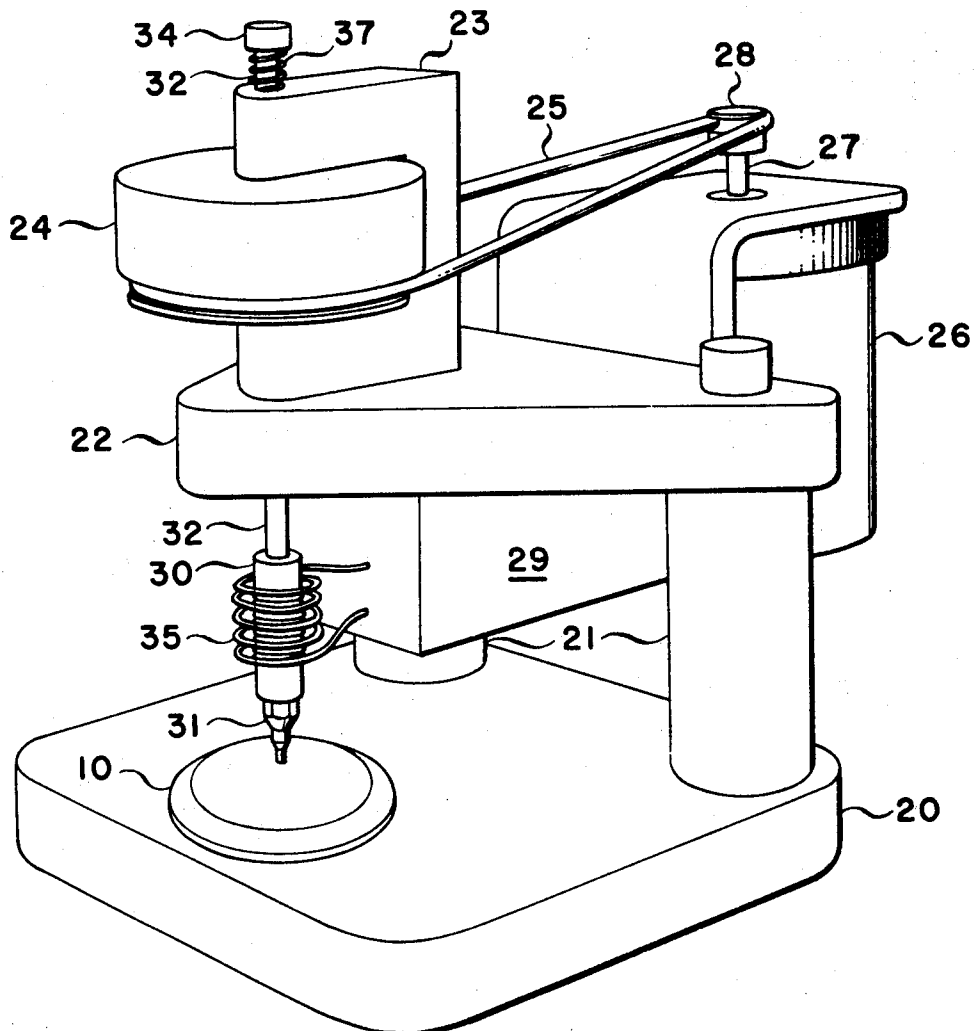
11 Claims, 7 Drawing Figs.

[52] U.S. Cl. 90/11,
29/593, 29/407, 29/625, 29/628, 77/55, 318/18

[51] Int. Cl. B23c 3/00

[50] Field of Search 90/11, 11.1;
77/55; 174/117.11; 318/18, 20.740; 29/593, 625,
628, 407; 33/(Inquired); 83/(Inquired)

ABSTRACT: Apparatus is described for removing electrical insulation such as that covering portions of conductive elements in flexible circuitry without damaging the conductive elements. The apparatus comprises an electric loop having inductive and variable capacitive means connected in series circuit, and a rotatable end mill forming both a conductive element in the electric loop and a functional element of the variable capacitive means. Drive means are provided for rotating the end mill in milling through insulation and thereby varying the capacitance of the variable capacitive means. Means are also provided for sensing the capacitance in the electric loop and in response to a predetermined value thereof to arrest drive imparted to the rotatable end mill by the drive means.



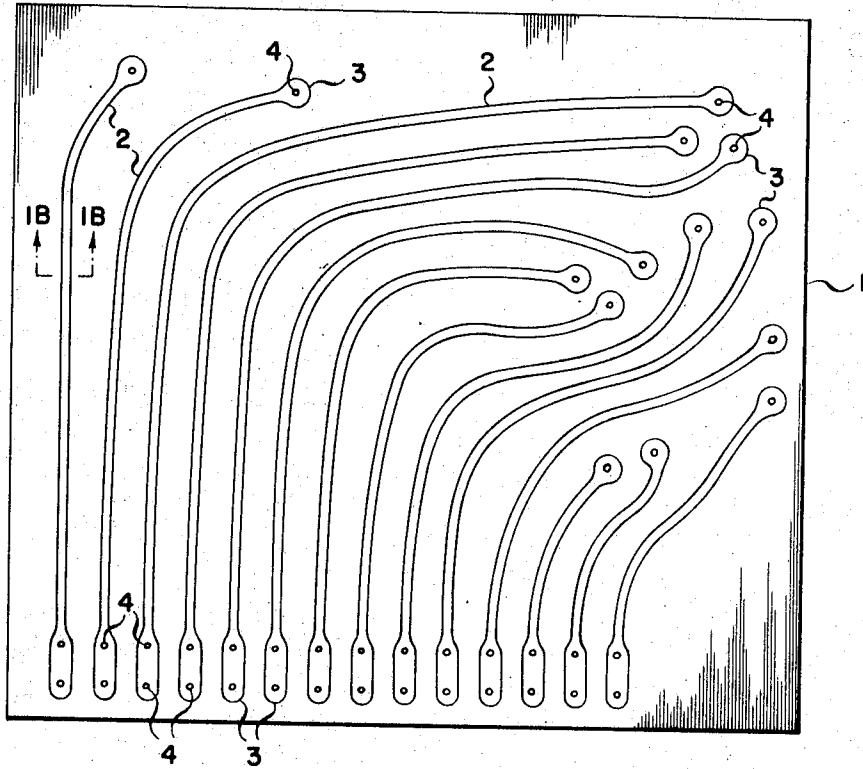


FIG. 1A

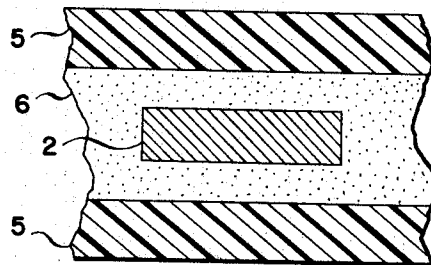
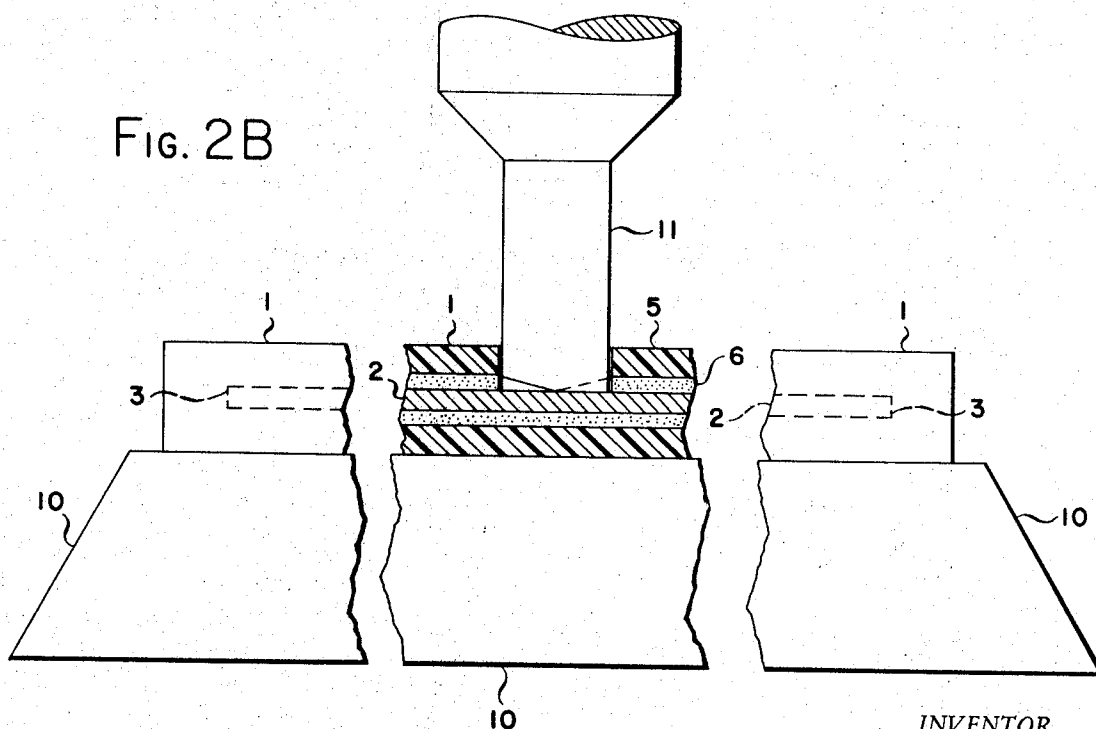
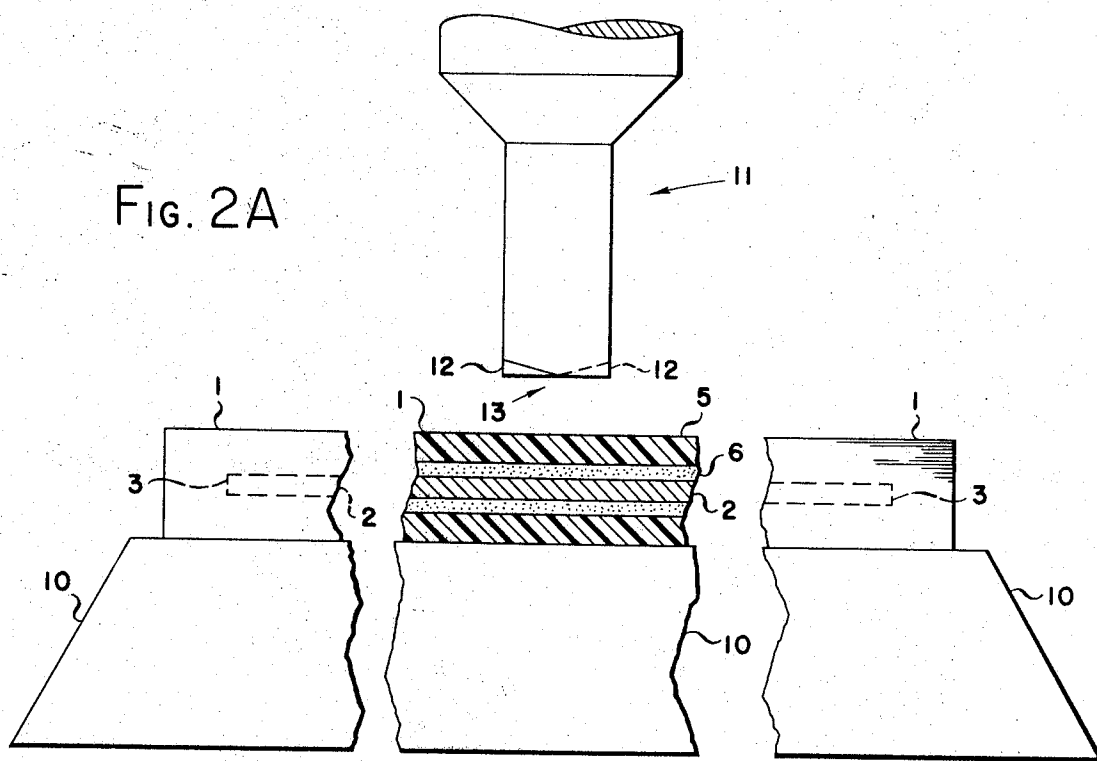


FIG. 1B

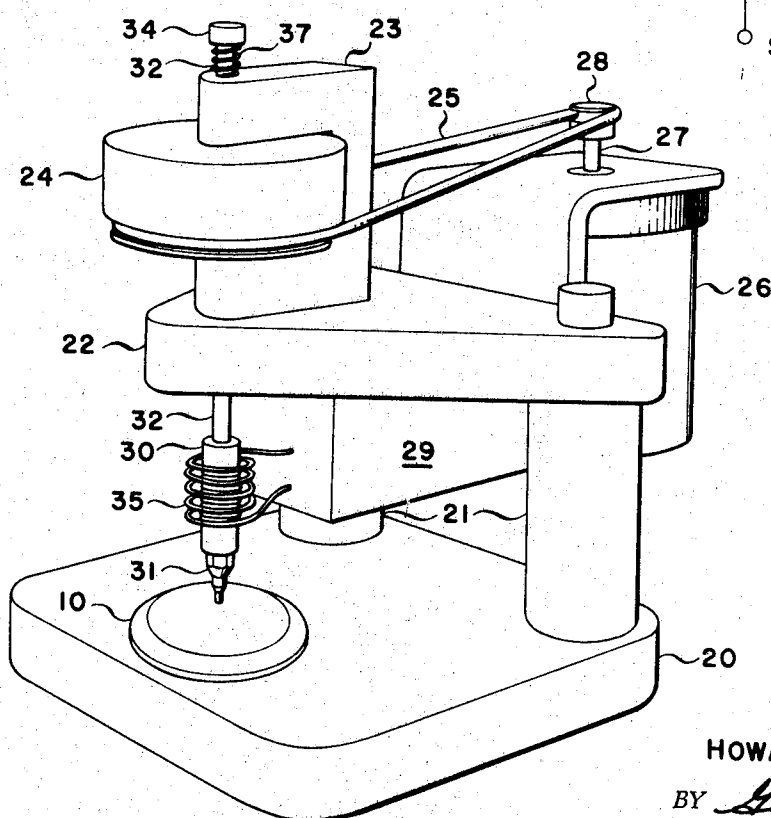
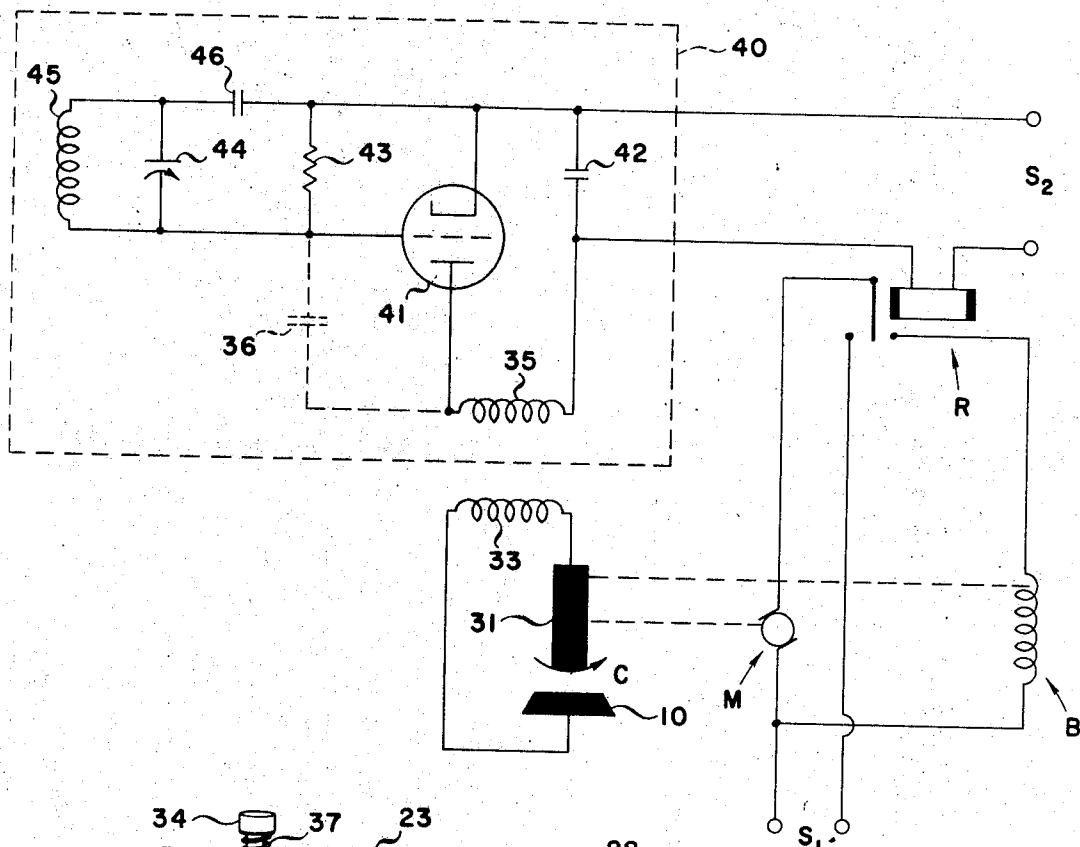
INVENTOR.
HOWARD A. BOLTZ

BY *George J. Sullivan*
Agent

Robert B. Kennedy
Attorney



INVENTOR.
HOWARD A. BOLTZ
BY *George Sullivan*
Agent
Robert B. Kennedy
Attorney



INVENTOR.
HOWARD A. BOLTZ

BY *George Sullivan*
Agent

Robert B. Kennedy
Attorney

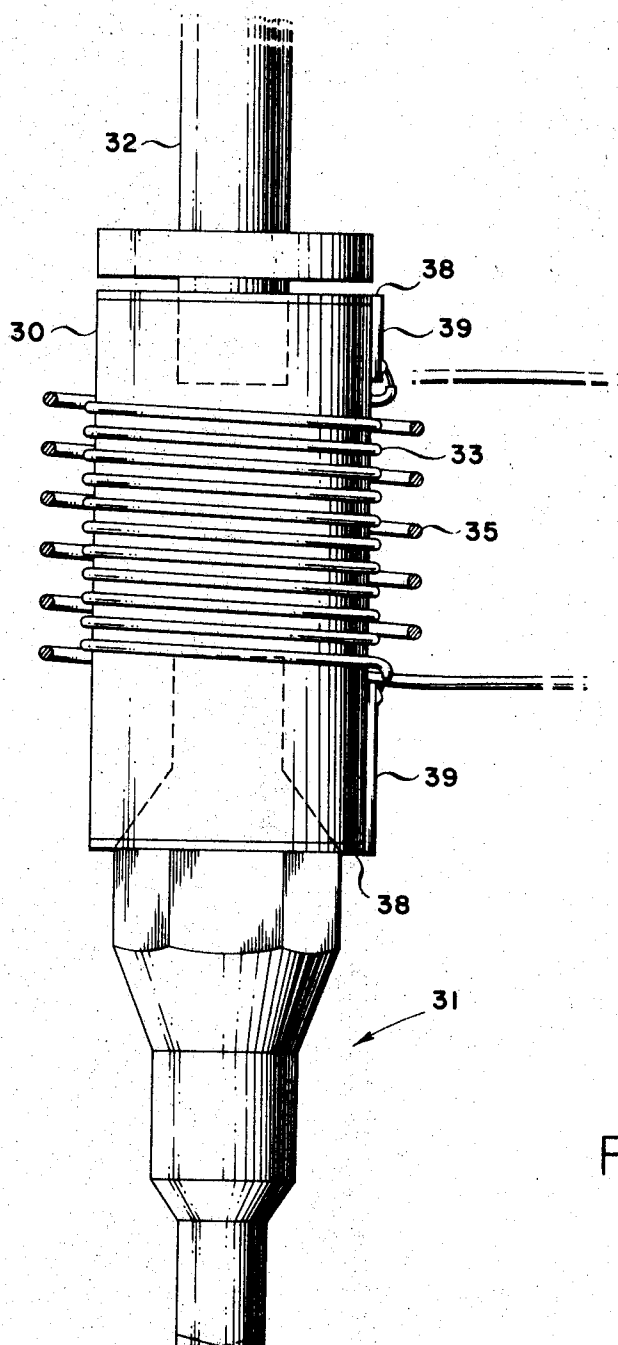


FIG. 4

INVENTOR.
HOWARD A. BOLTZ
BY *George Sullivan*
Agent
Robert B. Kennedy
Attorney

APPARATUS FOR REMOVING ELECTRICAL INSULATION

BACKGROUND OF THE INVENTION

This invention relates generally to apparatus for removing electrical insulation, and particularly to apparatus for removing insulation from portions of conductive elements in flexible circuitry.

Today flexible circuitry is in wide use in the electronic and aerospace industries. Units of flexible circuitry comprise an array of thin, co-planar, electrical conductors, most of which are usually unconnected. The array of conductors is sandwiched between thin sheets of flexible insulation. A unit of such flexible circuitry is designed to provide numerous electrical interconnections between component parts of electrical systems. To perform this function insulation must, of course, be removed from each operative conductor at two or more points therealong to permit conductive contact to be made between the conductor and the extraneous component parts which it serves to interconnect. Frequently, however, the insulation is quite tough and chemically inert which lends difficulty in removal, and in particular, difficulty in removal without damage to the underlying conductor. As used herein, the term "damage" means physical change to the conductor of such severity as to substantially impair the electrical and mechanical integrity of the conductor. Thus, where one or more dimensions of a conductor is merely reduced to some extent, without functional diminution, the conductor is not considered to have been damaged.

Heretofore many processes and apparatus have been used to remove such tough and inert insulation. These processes and apparatus have included the use of etching chemicals, induction-heated rotary tools, air abrasion through the use of fine alumina grits, microflame torches, rotary "cookie" cutters, manually-operated "X-acto" knives and machine-operated spot facers. Each, however, has met only limited success. The use of etching chemicals, for example, is messy, difficult to control and to localize, and is frequently ineffective in etching intermediate layers of adhesive. The manual use of knives is quite tedious and expensive.

Accordingly, it is a general object of the present invention to provide improved apparatus for removing insulation from insulated electrical conductors.

More specifically, it is an object of the present invention to provide improved apparatus for removing insulation from portions of an array of electrical conductors sandwiched between sheets of flexible insulation without damaging the conductors in the process.

Another object of the invention is to provide apparatus for removing insulation from selected areas of flexible circuitry with efficiency, effectiveness and economy.

SUMMARY OF THE INVENTION

Briefly described, the present invention is an improved apparatus for removing insulation from insulated electrical conductors, such as flexible circuitry elements, without damaging the conductors. The improved apparatus comprises an electric loop having inductive and variable capacitive means connected in series circuit, and a rotatable end mill forming both a conductive element in the electric loop and a functional element of the variable capacitive means. The apparatus further comprises drive means for rotating the end mill in milling through insulation and thereby varying the capacitance of the variable capacitive means. Means are also provided for sensing the capacitance in the electric loop and in response to a predetermined value thereof to arrest drive imparted to the rotatable end mill by the drive means.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1a is a plan view of a unit of flexible circuitry. FIG. 1b is a fragmentary, cross-sectional view of the flexible circuitry shown in FIG. 1a taken along line b—b.

FIGS. 2a and 2b are two sequential-operative side views, in elevation, of a unit of flexible circuitry undergoing insulation removal, a portion of the flexible circuitry being shown in cross-section.

FIG. 3 is a perspective view of apparatus embodying principles of the present invention.

FIG. 4 is an enlarged side view in elevation of a portion of the apparatus shown in FIG. 3.

FIG. 5 is a schematic diagram of the electrical circuitry of the apparatus illustrated in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in more detail to the drawing, there is shown in FIG. 1a a sample unit 1 of flexible circuitry comprising an array of laterally spaced, copper conductors 2 having terminal pads 3 at each end thereof. The terminal pads define apertures 4 through which extraneous contact pins may be inserted. The conductors and pads typically measure some 2 to 3 mils thick. As may be seen by reference to FIG. 1b, the upper and lower surfaces of conductors 2 are overlaid by an electrically insulative layer 5, such as a 2-mil thick layers of Kapton polyamide. The insulative layers are bound to each other and to the conductors and pads by two adhesive films 6 such as 1-mil thick films of fluorinated ethylene propylene.

Reference should next be made to FIGS. 2a and 2b for comprehension of principles by which apparatus functions when made and used in accordance with the invention. Here is depicted variable capacitive means comprising a metallic plate 10 and a rotatable end mill 11. The plate end mill are spatially separated and adapted for relative movement with respect to each other. In operation unit 1 of flexible circuitry is placed upon plate 10. End mill 11 is then set in fast rotation by appropriate drive means as indicated by the arrow. Either the end mill or the plate is moved with respect to the other causing teeth 12 of end mill cutting end 13 to contact the upper layer of insulation 5. The rotating teeth will then commence to mill through the insulation and the end mill will continue to advance towards plate 10. After milling through insulative layer 5 and the upper adhesive film 6, the cutting end 13 of the end mill will come into contact with conductor 2 and thereby occupy the position shown in FIG. 2b. Before the conductor is damaged by the cutting end the rotational drive imparted to the end mill is arrested. The end mill is then removed from the hole it has milled through the upper adhesive film and layer of insulation.

With continued reference to FIGS. 2a and 2b it can be appreciated that metallic plate 10 and metallic end mill 11 form effective, variable capacitive means when positioned adjacent each other and adapted for relative movement, as shown. With a unit of flexible circuitry inserted between the plate and end mill with a flexible, metallic conductor positioned between cutting end 13 and plate 10, the capacitance between the end mill and plate will be altered. The substitution of conductor 2 for a portion of the air dielectric separating the end mill and plate will serve to increase the capacitance of the variable capacitive means while the substitution of insulative layers and adhesive films 5 and 6 for air will typically serve to decrease the capacitance, depending on the dielectric constant of the material forming such layers and films. The capacitance of the variable capacitive means will also, of course, be increased as the end mill is advanced towards plate 10 since capacitance varies inversely with distance between capacitor plates.

Prior to such time that cutting end 13 contacts flexible conductor 2 the capacitance between end mill 11 and plate 10 may be expressed as $1/C = 1/C_1 + 1/C_2$ where C is the capacitance between end mill 11 and plate 10, C_1 the capacitance between the end mill and flexible conductor 2, and C_2 the capacitance between the flexible conductor and plate. As the end mill mills through the upper layers of insulation and adhesive C_1 will increase causing C also to increase until such time that cutting end 13 contacts flexible conductor

2. When contact is made C will become equal to C_2 which has remained fixed during the milling operation. When apparatus made in accordance with principles of the present invention senses C to approximate C_2 , rotational drive imparted to end mill 11 is arrested thereby preventing teeth 12 from biting deeply into conductor 2. Although a magnetic brake may be employed to arrest the rotational movement of the end mill, the axial force between the end mill and flexible circuitry may be easily adjusted to allow the force of friction alone to stop the milling action before conductor damage has occurred. Preferably the axial force is adjusted to cause the end mill to mill slightly into the conductor itself to insure that the exposed surface of the conductor will be completely free of insulation and adhesive. This action effectively provides a surface to which a good solder connection may later be made, while having avoided damage to the conductor. Furthermore, this milling operation is swift, precise and productive of a neat, well-defined hole in the overlaying layers of insulation and adhesive.

Turning now to FIG. 3, there is shown a preferred embodiment of structural features of the invention comprising a base 20 upon which is mounted two support posts 21 and a metallic plate or anvil 10. Posts 21 support arbor 22 upon which is mounted a C-shaped bearing yoke 23. The bearing yoke houses a vertically-movable pulley 24 which has a circumferential groove in which belt 25 resides. An electric motor, the outer casing of which is shown as 26, is also mounted to arbor 22. Motor drive shaft 27, having a relatively small pulley 28 affixed to the end thereof, projects from motor housing 26. Belt 25 is also looped over pulley 28 to provide drive linkage between pulleys 24 and 28. An electronic assembly 29 is slung beneath arbor 22.

Mounted to pulley 24 is shaft 32 which extends completely through C-shaped yoke 23 and arbor 22. A plunger cap 34 is mounted to the top of shaft 32 with a set of bearings interposed therebetween. Spring 37 is placed about the shaft to provide reciprocating action following depression of the plunger cap. Dielectric coil form 30 is mounted to the lower end of shaft 32 above anvil 10. End mill 31 is screwed into the lower end of the dielectric coil form as seen more clearly by reference to FIG. 4. An insulated inductor 33 is coiled about coil form 30 with one end of the inductor electrically connected to end mill 31 and the other end electrically connected to shaft 32. These connections are made by means of thin metallic washers 38 having tabs 39 to which the conductive ends of conductor 33 are soldered. Another insulated inductor 35, which for clarity is shown in cross-section, is coiled in spaced relation about inductor 33. Whereas inductor 33 is mounted to the rotatable coil form, inductor 35 is not.

FIG. 5 schematically illustrates the electronic circuitry of the embodiment shown in FIGS. 3 and 4. End mill 31 and plate 10 form variable capacitor C. Inductor 33 is connected across capacitor C to form an electric loop. The end mill is driven by motor M which is connected through relay R across a power supply S_1 . A magnetic brake B is also electrically connected across S_1 through relay R and magnetically linked to end mill 31. Motor M and magnetic brake B are so connected through relay R across power supply S_1 as to have either the motor or the brake operative, depending on the position of the relay, when the power supply is on.

A standard tuned-grid, tuned-plate oscillator 40 is connected to power supply S_2 through the energizing circuit of relay R. Oscillator 40 comprises triode 41 having a cathode connected to one terminal of S_1 and a plate connected through inductor 35 and relay R to the other terminal of S_2 . Capacitor 42 is connected across S_2 to provide a return RF path to the cathode. Bias resistor 43 connects the tube cathode and control grid. Variable capacitor 44 and inductor 45 are also connected, in parallel, across the tube cathode and grid through fixed capacitor 46.

The values of the various components of oscillator 40 are selected to provide tuned-grid and tuned-plate oscillations when the electric loop comprising inductor 33 and variable

capacitor C is inductively coupled to the oscillator by means of inductor 35 and when the capacitive value of variable capacitor C is less than a predetermined value. One such set of values appears in the following table, which table also includes some values of illustrated components which are extraneous to the oscillator itself. It should, of course, be understood that these selected values are not critical in producing acceptable performance.

TABLE I

Inductors—Turns-diameter	
33—	66½"
35—	6¾"
45—	8¼"
Capacitors—Pico-farads	
42—	1000
44—	25 max.
46—	25
Resistors—Megohms	
43—	1
Power supplies—Volts	
S_1 —	12 AC
S_2 —	90 DC
Vacuum tubes—Type	
41—	6CW4

When power supplies S_1 and S_2 are connected as shown, and a unit of flexible circuitry positioned between end mill 31 and anvil 10 within variable capacitor C, oscillator 40 will become operative. Oscillations in both the oscillator plate and grid circuits will frequency stabilize, the condition for oscillation being such that the resonant frequency of the grid circuit equals the resonant frequency of the plate circuit. Under this condition grid current flows in resistor 43 biasing the grid negatively which in turn causes the plate current to be small. As a result minimal current flows through relay R causing the motor contacts of the relay to occupy a closed position. With motor M now being connected across S_1 , end mill 31 is caused to rotate.

Next the milling operation is performed by depressing plunger cap 34 such as by finger action. Rotating teeth 12 will mill through the upper layers of insulation and adhesive therebeneath until they come into contact with conductor 2 of the flexible circuitry unit placed upon anvil 10. As cutting end 13 approaches conductor 2 the capacitive value of variable capacitor C will increase as described in the above discussions of FIGS. 2a and 2b until the cutting end comes into contact with the copper conductor. At this time the capacitance of the plate tuned circuit will rather abruptly increase thereby detuning the plate circuit. With the plate circuit now detuned from the grid circuit the voltage across the detuned plate circuit drops causing insufficient energy to be fed back to the grid circuit through the grid to plate inter-electrode capacitance, shown as 36, to sustain oscillations in the grid circuit. With triode 41 in a non-oscillatory mode practically no current flows through resistor 43. Hence the tube grid is no longer negatively biased. The plate current at this time will increase causing relay R to open the motor circuit and to close the brake circuit. Drive delivered by motor M to end mill 31 will thus be arrested and braking action by brake B applied so as to prevent teeth 12 from damaging conductor 2. As stated above, however, the presence of the magnetic brake is entirely optional inasmuch as the frictional force between cutting end 13 and conductor 2 may be adjusted for appropriate dynamic braking action following the arrest of drive by motor M.

It should be understood that the just-described embodiment is merely illustrative of principles of the present invention. Obviously, many modifications may be made thereto without departure from the spirit and scope of the invention as set forth in the following claims.

I claim:

1. Apparatus for removing insulation from insulated electrical conductors such as flexible circuitry elements which are disposed within variable capacitive means of the apparatus without damaging the conductors, comprising:

1. an electric loop having inductive and variable capacitive means connected in series circuit;
2. a rotatable end mill forming a conductive element in said electric loop and a functional element of said variable capacitive means;
3. drive means for rotating said rotatable end mill in milling through insulation of an insulated electrical conductor positioned within said variable capacitive means and in the process varying the capacitance of said variable capacitive means; and
4. means for sensing the capacitance in said electric loop and in response to a predetermined value thereof to arrest drive imparted to said rotatable end mill by said drive means;

Whereby an insulated electrical conductor may be positioned within said variable capacitive means and said end mill driven through a portion of its insulation and into contact with the conductor causing the capacitance across the variable capacitor to reach said predetermined value and thereby cause drive imparted to the rotating end mill to be arrested before the end mill damages the conductor.

2. Apparatus in accordance with claim 1 wherein said inductive means is mounted to said rotatable end mill.

3. Apparatus in accordance with claim 1 wherein said rotatable end mill has a plurality of metallic teeth defining a cutting end thereof, and wherein said variable capacitive means comprises said cutting end and a metallic plate separated from said cutting end by an air gap.

4. Apparatus in accordance with claim 1 wherein said rotatable end mill is axially movable.

5. Apparatus in accordance with claim 1 wherein said sensing and arresting means comprises a tuned-grid, tuned-plate oscillator.

6. Apparatus in accordance with claim 5 wherein said tuned-grid, tuned-plate oscillator is inductively coupled to said electric loop.

7. Apparatus in accordance with claim 5 wherein said tuned-grid, tuned-plate oscillator comprises a triode and an inductor connected across the cathode and anode of said triode through a fixed capacitor.

8. Apparatus in accordance with claim 7 wherein said inductor is positioned in spaced relation about said inductive means.

9. Apparatus in accordance with claim 8 wherein said inductive means is mounted to said rotatable end mill.

10. Apparatus in accordance with claim 7 further comprising means for magnetically braking said rotatable and axially movable end mill when drive imparted to said rotatable end mill is arrested by said sensing and arresting means.

11. Apparatus for removing insulation from insulated electrical conductors comprising:

1. a metallic member;
2. a metallic, rotatable end mill mounted for relative movement with respect to said metallic member;
3. an inductor mounted in spaced relation to said rotatable end mill and having one terminal electrically connected to said end mill and another terminal electrically coupled to said metallic member;
4. electromotive drive means for rotating said end mill as an aid to milling through insulation of an insulated electrical conductor positioned between said metallic member and said end mill;
5. means inductively coupled to said inductor for sensing the variable capacitance between said metallic member and said rotatable end mill which is mounted for relative movement with respect to said metallic member; and
6. means for arresting drive imparted to said rotatable end mill by said electromotive drive means when the sensed capacitance between said metallic member and end mill has reached a predetermined value.

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