

United States Patent

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 [73] Assignee **Pennwalt Corporation**

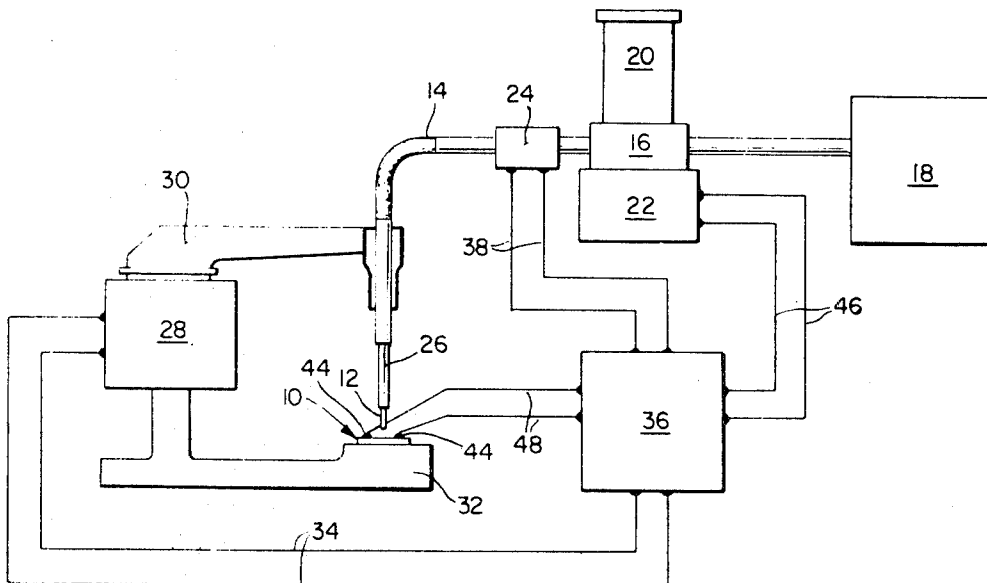
[56] **References Cited**
UNITED STATES PATENTS
 2,773,332 12/1956 Buchman et al. 51/15
 3,270,463 9/1966 Ashworth et al. 51/8
 3,425,166 2/1969 Best et al. 51/14
FOREIGN PATENTS
 390,476 6/1931 Great Britain. 51/319

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[54] ABRADING METHOD 4 Claims, 4 Drawing Figs.

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 [51] Int. Cl. B24c 1/00
 [50] Field of Search. 51/319,
 320, 8, 14, 15

ABSTRACT: Miniature electrical resistors having a resistive film on a nonconductive substrate are abrasively trimmed to increase their resistance to a desired value by moving an abrasive jet between the resistor terminals, while measuring the rate of resistance increase, and then stopping and reversing the movement of the jet at a projected point in time when resistance has increased to the desired value. Capacitors and other electrical elements can be trimmed by this method.



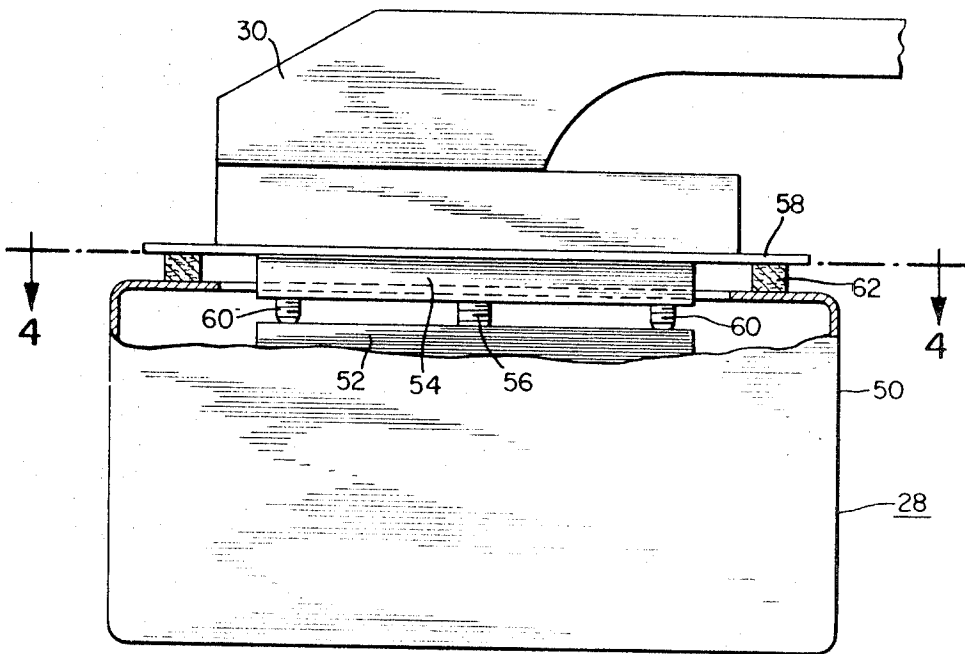


Fig. 3

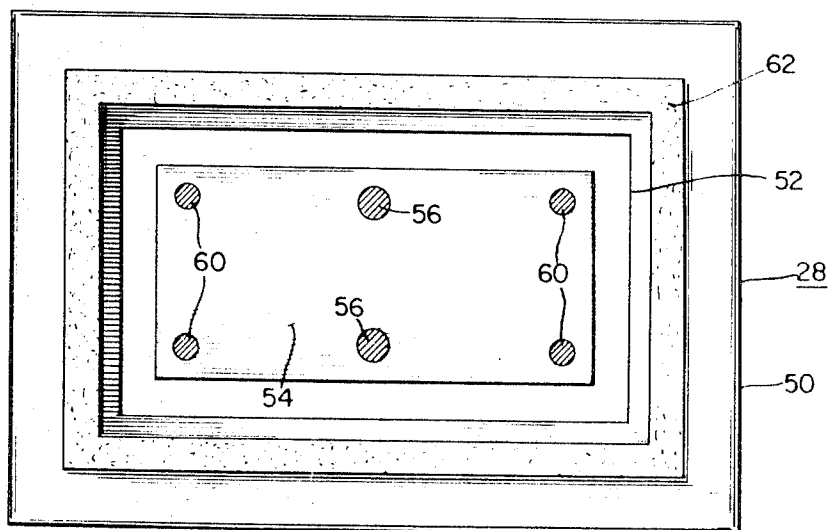


Fig. 4

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ABRADING METHOD

This application is a division of application Ser. No. 662,112, filed Aug. 21, 1967, now U.S. Pat. No. 3,534,503, dated Oct. 20, 1970.

This invention relates to a method for carefully removing material from a workpiece such as a miniature electrical resistor.

Miniature electrical resistors comprise a conductive film of electrically resistant material on a nonconductive substrate between spaced terminals. Such miniature resistors are made by first printing a slightly excessive amount of film on the substrate and then removing a portion of the film between the terminals so as to reduce the cross-sectional area disposed between the terminals until the electrical resistance of the element is adjusted upwardly to the desired value. Although various methods have been employed heretofore for removing material coated on a substrate, the present invention is directed to a method for removing material by abrasion.

The basic abrading apparatus comprises an air supply, a powder reservoir with vibrator and mixing chamber, and a supply conduit fitted with an appropriate nozzle. Under pulsation from the vibrator abrasive powder trickles into the pressurized airstream, the amount depending on the amplitude of vibration. A rheostat may be employed to regulate the amplitude of vibration and, consequently, the intensity of abrasive cutting action.

To the basic abrading apparatus is added an electronic control and measuring system, also a controlled drive with fast stop-action for the nozzles. It is contemplated that a workpiece such as a resistor will be placed in a holder. Thereafter, on signal the machine automatically lowers probes over resistors to be trimmed, measures them, starts the abrasive jet flow and nozzle motion, continues to monitor resistance, and stops the entire proceedings when predetermined resistance values have been reached.

The method of the present invention therefore involves measuring the rate at which the electrical resistance of the resistor is increased with respect to the speed of movement of the jet, then projecting the additional time required to further increase the resistance to the desired value, and stopping and reversing the movement of the jet at the point in time thus determined. With proper compensation for overshoot, the milliseconds of time elapsed between initiating and effecting stopping of travel of the jet, together with a highly responsive braking and reversal mechanism, trimming can be accomplished with a high degree of accuracy.

Provision is made to protect the traversing mechanism from damage by spent abrasive particles by interposing a seal between a margin surrounding an opening in its housing and the appended parts which transmit motion to the nozzle, all of which is described hereinafter in greater detail.

In the Drawings:

FIG. 1 is a schematic illustration of apparatus constructed and arranged for carrying out the invention;

FIG. 2 is a plan view of a miniature electrical resistor, shown greatly enlarged, of the type which can be trimmed abrasively according to the present invention;

FIG. 3 is a fragmentary elevational view of the apparatus, with portions broken away, illustrating the traversing mechanism in detail; and

FIG. 4 is a horizontal sectional view through the apparatus, taken along lines 4-4 of FIG. 3.

The illustrated abrading apparatus will now be described as to the trimming of a thick-film resistor or other workpiece designated generally by the numeral 10, utilizing a high velocity abrasive stream issuing from a nozzle 12. The latter is supplied through a supply conduit 14 by a mixing chamber 16 where dry, filtered, pressurized air at about 85 p.s.i. from a compressor 18 is uniformly mixed in the desired proportions with abrasive powder from a reservoir 20. By means of a unique arrangement more fully described in the present inventor's application Ser. No. 365,123, filed May 5, 1964, now

U.S. Pat. No. 3,344,524, granted Oct. 3, 1967, a vibrator 22 is employed to apply vibrations to the chamber 16. This arrangement can produce an automatically replenished trickle of about 3 to 5 grams per minute of aluminum oxide or other abrasive powder having an average particle size of 27 microns, from the reservoir 20 through a passageway (not shown) to the mixing chamber 16 for combining with the pressurized air.

The flow of airborne abrasive particles is initiated by the energization of a solenoid operated pinch valve 24 in the upstream end of the supply conduit 14, that is, at the outlet of the mixing chamber 16. The nozzle 12 will have a restricted orifice, e.g. 0.018 inch diameter, of much smaller cross-sectional flow area than the supply conduit 14, and thus the entire system is pressurized. In order to achieve uniform cutting action the apparatus is arranged to provide a uniform concentration of particles in a constant airstream issuing from the nozzle at about 40 to 80 p.s.i.

The supply conduit 14 may be a flexible hose of abrasion resistant material at the end of a length of rigid tubing, and it is preferred that the terminal or end portion adjacent the nozzle 12 be of rigid tubular construction so that it can serve as nozzle holder 26 capable of having its movements accurately controlled by a traversing mechanism 28 connected thereto by a rigidly constructed arm 30. The nozzle holder 26 is suitably journaled in the extended free end of the arm 30, in upright position above a holder 32 for the workpiece 10. Further details of construction of the traversing mechanism 28 appear herein and it is noted here that the mechanism 28 serves to move the nozzle 12 by its holder 26 transverse to the longitudinal extent of the holder, or into and out of the plane of the drawing illustrating the apparatus, whereby the abrasive stream is traversed along the length of the workpiece to cut or abrade along the line of travel. The traversing mechanism 28 responds to signals received via conductors 34 from a control 36 to move a controlled distance first in one direction and then usually in opposite or reverse direction upon completion of an abrading operation. The control 36 also sends energizing current through conductors 38 to the solenoid of pinch valve 24 to effect its closing upon completion of an abrading operation; but otherwise during abrasive trimming the pinch valve 24 is held open.

The workpiece 10 shown in FIG. 2 is an electrical resistor having a thick, electrically resistive film 40 printed on a correspondingly shaped substrate and having a pair of terminals 42 joined to opposed parallel edges thereof. As shown, the resistor 10 has been trimmed between the lines designated by the letters A and C. Phantom line B indicates the point at which a stop and reverse signal was issued from the control 36; and the trimmed area lying between lines B and C represents the amount of film 40 trimmed by overshooting during the 5 milliseconds of elapsed time between issuance of the signal and the actual point of stopping. Broken line D represents the point at which abrasive flow ceased during reverse movement of the nozzle, approximately 20 milliseconds following issuance of the stop signal at B. It can be seen that abrasive material continues to flow as the nozzle travels from B to C and then in reverse direction from C to D. Obviously no material is removed from the film 40 during reverse movement of the nozzle between C and D because the material was already removed during forward motion between A and C. The present invention recognizes that control 36 must anticipate the removal of material from film 40 while overshooting between B and C.

Referring again to FIG. 1, a pair of probes 44 are connected during trimming between terminals 42 and control 36 by conductors 48 so that the electrical resistance of the resistor 10 can be continuously monitored by the control 36 as work proceeds.

The vibrator 22 may be connected as shown to the control 36 by conductors 46. The concentration of abrasive particles in the abrasive jet can be set by adjusting the amplitude of vibrations applied to the mixing chamber in direct relation to the desired abrasive capability of the jet since the cutting ac-

tion of the abrasive stream corresponds to the abrasive concentration.

The traversing mechanism 28 of FIGS. 3 and 4 includes a housing 50 enclosing a motor (not shown) in driving relationship with a motion translating mechanism 52. The latter translates rotary motion of the motor into horizontal linear motion in the illustrated arrangement. Such motion is transmitted from the mechanism 52 through a plate 54 (connected thereto by bolts 56), a generally flat platform 58, and an arm 30 to the nozzle holder 26. The plate 54 is disposed in an opening in the generally flat top wall of the housing 50, with the marginal portions of the housing about the opening spaced from the plate 54 to limit the horizontal motion thereof within the confines of the opening and to correspondingly limit the linear motion of the mechanism 52.

Between the plate 54 and the motion transmitting mechanism 52, a setscrew 60 is interposed at each of the four corners thereof. The setscrews 60 serve to adjust the spacing between the top surface of the housing 50 and the bottom surface of the platform 58, and also to adjust the compression of a seal member 62 disposed therebetween. The seal 62 is preferably made of felt or other soft and fine solids impervious material, and it is secured by an adhesive cement to the top wall of the housing 50 so as to extend entirely around the opening therein. With the margin of the platform 58 slidably resting on the seal member 62, access to the interior of the housing 50 through the top opening is closed. And by adjustment of the setscrews 60 the compressive force on the seal 62 can be set to maintain a good seal and yet permit free sliding motion of the platform 58. To assist in free sliding motion of the platform 58 on the seal 62 the lower surface of the platform 58 is provided with a low friction coating such as Teflon.

According to the method of the present invention, the electrical resistor 10 is trimmed by directing a jet of airborne abrasive particles toward the film 40 at close range, while moving the jet at constant forward speed across part of the surface of the film in a path between the terminals 42 so as to reduce its cross-sectional area. While moving the jet the increasing resistance of the resistor 10 is continuously measured and the additional time required to further increase resistance to the desired value can be projected. After offsetting the time involved in removing additional material during overshooting, as described with reference to FIG. 2, the precise point in time for initiating stopping and reversing can be determined. As a result, reversal of the moving jet is effected after compensation for overshooting so that the film material remaining has the desired electrical resistance within a high degree of accuracy. With forward nozzle travel speeds of 1 inch per minute, resistor values within plus or minus 1/10th percent can be achieved without difficulty; with trimming speeds up to 6 inches per minute, accuracy within 3/10ths percent can be obtained; and where less accuracy is required, trimming speeds can be increased to and beyond 15 inches per minute.

When performing highly accurate trimming tasks at the slower speeds, it is nevertheless desirable and permissible to effect reverse movement of the nozzle at maximum speed. For example, during trimming on forward motion it may be that 1 inch per minute of travel speed is desirable to obtain the desired accuracy, and reverse movement can be accomplished at a maximum travel speed of say 15 inches per minute so as to minimize the total time of each trimming cycle.

For maximum accuracy, trimming should be accomplished by moving the nozzle, not only at constant forward speed, but also with a constant distance between the nozzle 12 and the film 40.

The control 36 may incorporate a 4-wire resistance limit bridge, integral to the electrical control system, for monitoring the resistor as it is being trimmed and sending a signal to the pinch valve 24 and to the traversing mechanism 28 in the manner and at the time described.

Although the invention has been described as applied to the trimming of electrical resistors, the invention is also applicable to the trimming of other kinds of electrical elements such as capacitors. Miniature capacitors are well known to be made of a dielectric material between two conductive members to which terminals are connected. In such case the capacitance of the capacitor is measured as trimming of a metal conductive member (and/or dielectric material) takes place to monitor the changing electrical value as trimming progresses. It follows, therefore, that as expressed in the claims, the term "electrical value" or "value" is applicable to measurement of resistance (ohms), as well as capacitance (farads, microfarads, or micromicrofarads) or any other kind of unit of electrical value susceptible of measurement. And the method and apparatus are applicable to workpieces other than components of electrical circuitry, particularly when measurement of an electrical value thereof is indicative of the amount of material present, and thus indicative also of the extent of abrasion accomplished by the method and apparatus. Likewise, the method and apparatus can be employed whether trimming effects an increase or decrease in the electrical value being measured. Trimming of a capacitor, for example, may produce a decrease in capacitance; and this measurement may be employed to effectively control trimming downwardly to the desired capacitance in the same manner as upward adjustments of resistance of a resistor. In some instances the measurement may be of impedance or inductance, depending of course on the value or characteristic of interest.

What I claim is:

1. In a method of adjusting to a desired value the electrical value of an electrical element comprising a film on a nonconductive substrate bridging spaced terminals, by abrading a portion of said film with abrasive particles having a nozzle as a source, the steps of:

- a. holding element in a workpiece holder,
- b. providing a high velocity jet of airborne abrasive particles,
- c. directing said jet toward the film at close range,
- d. moving said jet linearly in a first direction across part of said film in a path between said terminals to reduce the cross-sectional area of said film between said terminals,
- e. stopping and reversing the movement of said jet upon reaching the desired electrical value of said element at a faster rate of travel during reverse movement than during movement in said first direction.

2. A method according to claim 1 wherein said film is electrically resistive, conductive material, the electrical resistance of which is increased by reducing the cross-sectional area thereof between said terminals.

3. The method according to claim 1 wherein the moving of said jet in step (d) is performed at a constant rate of travel with a constant distance between said film and the nozzle.

4. The method according to claim 1 wherein said step of providing a high velocity jet of airborne abrasive particles includes mixing pressurized air and a stream of abrasive particles in a mixing chamber, further including vibrating said mixing chamber at a constant frequency of vibration, and setting the concentration of abrasive particles in said jet by adjusting the amplitude of vibration applied to said mixing chamber in direct relation to the desired abrasive capability of said jet.