

Jan. 28, 1947.

J. A. BECKER ET AL
METHOD OF MAKING RESISTORS

2,414,793

Filed June 29, 1945

FIG. 1

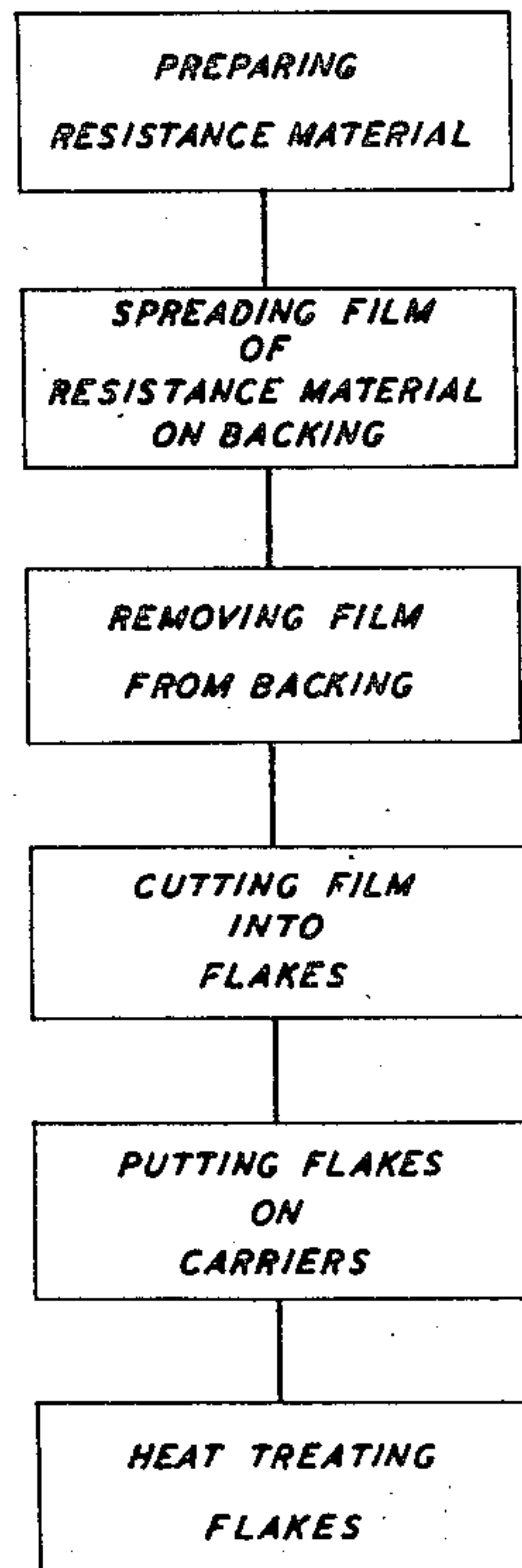
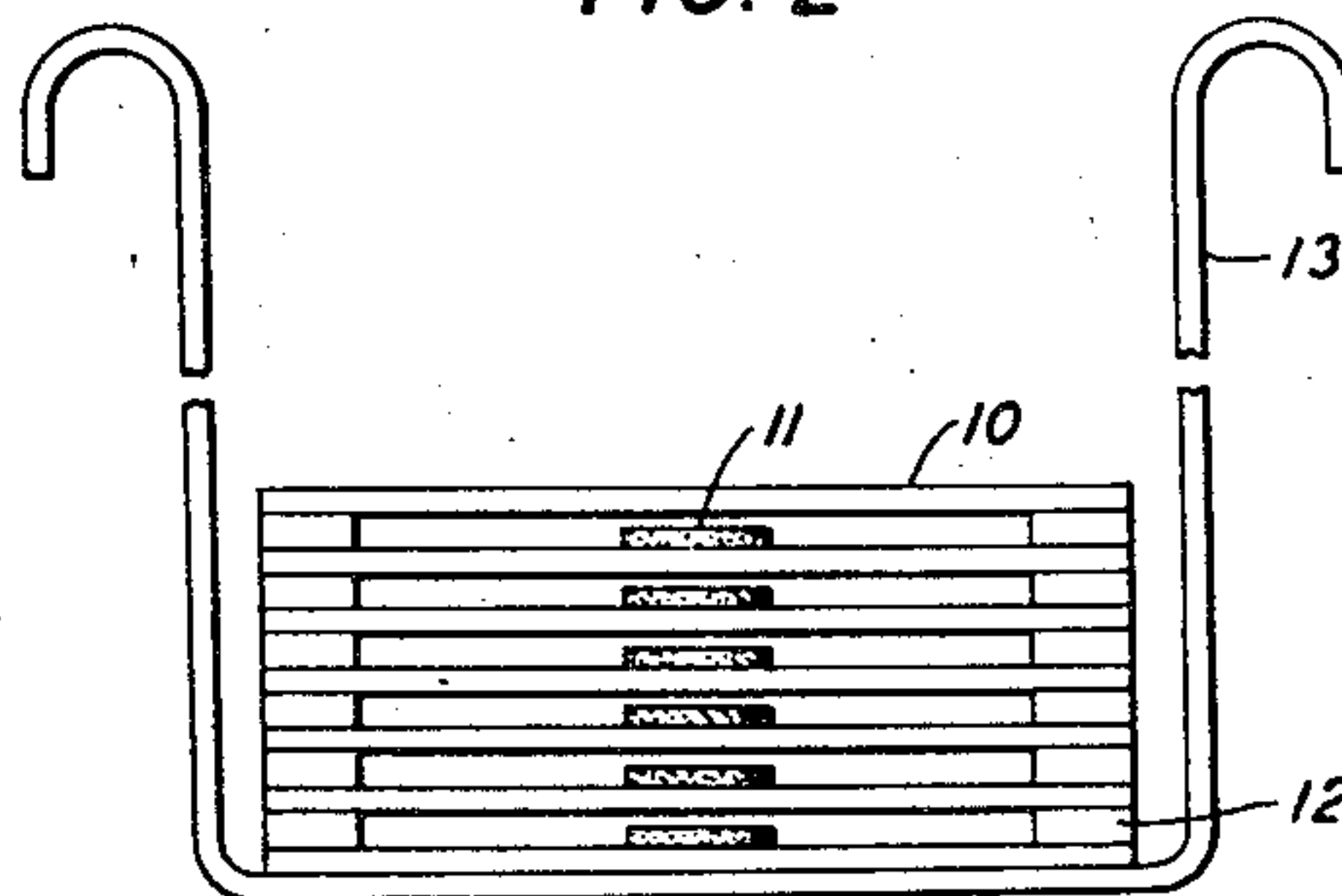


FIG. 2



INVENTORS: J. A. BECKER
H. CHRISTENSEN
BY
Walter C. Kiesel
ATTORNEY

UNITED STATES PATENT OFFICE

2,414,793

METHOD OF MAKING RESISTORS

Joseph A. Becker, Summit, and Howard Christensen, Springfield, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 29, 1945, Serial No. 602,260

8 Claims. (Cl. 201—63)

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This invention relates to resistors and more particularly to small, thin-film resistors and to methods of making them.

Resistors, the resistance of which varies greatly with changes in temperature, have been called "thermistors," a term derived from "thermal" and "resistor." Wherever the term "thermistor" may appear in this specification or the appended claims such a resistor is intended.

In some applications of thermistors, particularly those in which response to small amounts of radiant heat is required, it has been found desirable to make the thermistor elements very thin and of small area. Because of the fragility of such thin elements it has been found necessary to form them on a backing member or body, which acts as a supporting means during use. Heretofore such devices have usually been made by applying a very thin, small area film of suitable resistance material to a surface of an insulating body. Suitable electrical connections are made to spaced portions of this film. Since the supporting body is of insulation the electrical currents flow only in the thin film of resistance material. The body, however, which of necessity is relatively massive with respect to the small piece of film has a marked thermal effect on the assembly. Because the film is attached to the body during manufacture and remains permanently attached thereto, the body material must be selected to conform to manufacturing requirements of the film. For example, thermistors made from various metal oxide materials must be subjected to a relatively high temperature heat treatment during manufacture. This necessitates selecting a backing body of a material that will withstand such a heat treatment. This limitation on the selection of materials for the backing or supporting bodies may preclude the use of certain materials that would be particularly suitable as a backing body during the use of the device. Furthermore, it may be desirable in some cases to employ such a small thermistor element without a backing.

It is an object of this invention to make a relatively small area, thin-film resistor, that is sufficiently self-supporting to render it independent of any particular backing body.

A feature of this invention resides in a series of correlated manufacturing steps resulting in a tiny flake of resistance material having sufficient strength and rigidity to allow it to be separated from any backing body that may be used in its manufacture and to be mounted on a backing member chosen for the use rather than from the

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manufacturing viewpoint; or to be used without a backing member.

These and other objects and features of this invention will be more fully and clearly understood from the following description of an exemplary embodiment thereof taken in connection with the appended drawing in which:

Fig. 1 represents schematically the various steps involved in the making of resistor elements; and

Fig. 2 shows one form of a carrier means for supporting resistor elements during heat treatment.

In the making of tiny flake thermistors in accordance with this invention, various materials having a relatively high resistance-temperature coefficient may be employed. For example, one or more of the oxides of manganese, nickel, cobalt, copper, iron, or zinc may be used.

Thermistor flakes may be made in accordance with this invention of a few microns to several tens of microns in thickness. For example from 3 to 20 microns thickness. For some applications, this film of material may be made into strips from 0.1 to 2 or 3 millimeters wide and from 3 to 7 millimeters long. Of course, other shapes and dimensions may be used where necessary.

In order to provide a thin, sufficiently homogeneous film of resistance material, attention must be paid to the particle size of the material used. It has been found desirable to employ a granular material having a maximum particle size about one-hundredth the desired thickness of the completed flake. A quantity of the prepared resistance material is thoroughly mixed, as in a ball mill, with a temporary binder and a volatile solvent. A plasticizer, such as dimethyl phthalate may be added where desirable. Some suitable binders are polymerized methacrylates (e. g. isobutyl methacrylate) polyvinyl chloride, and cellulose acetate butyrate. A thin film of this prepared mixture is then spread on a smooth surface of a flat plate, for example, a sheet of glass, to a thickness of several microns. This may be done by spraying or preferably by spreading a drop or two of the mixture over a portion of the surface of the plate by means of a properly spaced straight edge. The filmed plate is then placed in a dust-free atmosphere and the volatile solvent allowed to evaporate.

The dried film may be removed from the plate in several ways. The plate may be immersed in a bath of water at about 40° C. and allowed to attain water temperature. A corner of the film is then gently lifted with a suitable device such

as thin razor blade, allowing the water to raise the film away from the plate. The freed film may then be removed from the water by suitable means such as a fine mesh screen. The film is then dried, for example, in an oven having a temperature of about 100° C. The film of resistance material may be also removed by spreading a thin film of water over it for a short time and then lifting the corner with a suitable instrument, as in the immersion technique just described. Another way of removing the film is to place a sheet of moist lint-free paper over the film for a short time to wet it, then to remove the paper and to lift the film as before.

When the film is thoroughly dried, it is cut into bits or flakes of suitable size and shape. At this stage due to the presence of the temporary binder, the film is relatively tough and may be safely handled, if a reasonable degree of care is used. Cutting may be done with any suitable means such as a small shear or by placing the film on a plane surface and cutting with a thin knife or razor blade.

Another way of obtaining small bits of resistance film is to divide the film on the flat plate before the solvent evaporates. This may be done with a straight edge and scribe or by means of other suitable instruments. The divided film may then be dried and the individual bits removed separately.

Each flake or bit of film is then placed on a very flat surface of a plate of refractory material. These plates may be of platinum coated with aluminum oxide or other suitable material to avoid any tendency of the flakes to stick thereto during the subsequent firing operation. Slabs of ceramic material, such as aluminum oxide, may be used in place of the coated metal plates. These plates are of relatively large area with respect to that of the flake in order to insure uniform distribution of heat across the flake, thereby inhibiting any tendency of the flake to warp due to uneven heating. A plurality of the carrier plates are stacked with spacers between them in preparation for firing. The spacers are slightly thicker than the resistor flakes so that the flakes will be allowed to shrink during firing without mechanical constraint.

These stacks of loaded carrier plates may be placed in a suitable support for suspension in a furnace. For example, as illustrated in Fig. 2, a plurality of supporting plates 10 each loaded with a flake 11 and separated from adjacent plates by spacers 12, may be mounted on the support or hanger means 13. The support means may be simple U-shaped elements of wire having overturned upper ends, two or more of which may be used to support a stack, the front one only being shown in Fig. 2. If desired, cross bars may be employed to connect two or more hangers together into a rack.

A rack of loaded plates may then be placed in a suitable furnace for removal of the temporary binder and sintering. Where the binder is polymerized methacrylate material, the temperature may be gradually raised to about 240° C. to depolymerize and drive off this binder. Other techniques may be employed for removing the temporary binder, depending on its characteristics. Usually they will include gentle heating.

After the binder is removed, the temperature may be raised to about 600° C. and then later in several steps to about 1100° C. Most of the sintering of the flakes takes place in this range. The temperature may be further raised to some

point between 1100° and 1450° C. to complete the sintering, depending on the material from which the flakes are made. The flakes and their support means are then allowed to cool and the flakes are removed from the supporting plates.

The completed flakes may then be supplied with terminals and mounted in a manner suitable for the situation in which they are to be employed.

The heat treating operation should be carried on carefully with gradual changes in temperature in order to avoid warping of the thermistor flakes. It is noted in this connection that the spacers 12 between the plates 10 are so placed that the volatilized binder and the atmosphere of the furnace can circulate through the space between plates without hindrance. This allows complete removal of the binder and aids in distribution of heat throughout the assembly.

It is believed obvious that other equivalent instrumentalities may be employed in place of those particularly pointed out in the foregoing illustrative embodiment of the process of this invention. It will therefore be understood that it is not intended to limit the invention by this particular disclosure but by the scope of the appended claims only.

What is claimed is:

1. The method of making resistor elements of small area and of the order of several microns thickness that comprises finely dividing metal oxide resistance material to a maximum particle size of about one-hundredth the desired thickness of a resistor element, mixing this material with a polymerized methacrylate and a volatile solvent to form a thin liquid, spreading a uniform film of the mixture on a smooth plate to a thickness of several microns, allowing the solvent to evaporate in a dust-free atmosphere, immersing the filmed plate in water at about 40° C. until it attains the water temperature, gently lifting a portion of the film to allow the water to force said film from the plate, removing the film from the water on a fine mesh screen, drying the film on the screen at about 100° C., cutting the film into small bits of desired size, placing each bit of film on a very flat plate of refractory metal the surface of which has been coated with aluminum oxide, stacking a plurality of the loaded plates with spacers between them, gently heating the stacked bits to drive off the methacrylate, then raising the temperature gradually to an extent sufficient to sinter the resistance material, allowing the stack to cool, and removing the resistor elements from the plate.

2. The method of making resistor elements of small area and of the order of several microns thickness that comprises finely dividing metal oxide resistance material, mixing this material with a temporary binder and a volatile solvent to form a liquid, spreading a uniform film of the mixture on a smooth plate to a thickness of several microns, allowing the solvent to evaporate, removing the film from the plate, cutting the film into small flakes of desired size, and heat treating said flakes first gently at a low temperature to remove the temporary binder and then at a temperature sufficiently high to sinter the resistance material into self-sustaining bodies.

3. The method of making resistor elements of small area and of the order of several microns thickness that comprises finely dividing metal oxide resistance material to a maximum particle size of about one-hundredth the desired thickness of a resistor element, mixing this material with

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isobutyl methacrylate and a volatile solvent to form a liquid, spreading a uniform film of the mixture on a smooth, flat, plate to a thickness of several microns, allowing the solvent to evaporate in a dust-free atmosphere, immersing the filmed plate in water at about 40° C. until it attains water temperature, gently lifting a corner of the film to allow the water to force it from the plate, removing the film from the water on a fine mesh screen, drying the film on the screen at about 100° C., cutting the film into small bits of desired size, placing each bit of film on a very flat plate of platinum, the surface of which has been coated with aluminum oxide, stacking a plurality of the loaded metal plates with spacers between them, inserting the stack in a furnace and gently heating to depolymerize and drive off the methacrylate, then gradually raising the temperature sufficiently to sinter the resistance material, allowing the stack to cool, and removing the completed resistor elements from the platinum plates.

4. The method of making small area, thin-film resistor elements that comprises applying a thin film of resistance material to a flat plate, removing the film from said plate, dividing the film into pieces of desired shape and area, placing the pieces of film on a heat distributing carrier to inhibit warping of said film during heat treatment, and heat treating the pieces of film to form them into dense, self-sustaining resistor bodies.

5. The method of making small area, thin-film resistor elements that comprises finely dividing metal oxide resistance material, mixing this material with a temporary binder, spreading a uniform film of the mixture on a smooth flat plate, removing the film from the plate, cutting the film into small bits of desired size, placing each bit of film on a very flat plate, stacking a plu-

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ality of loaded plates with spacers between them, subjecting this assembly to heat to remove the temporary binder from and to sinter the resistance material, allowing the stack to cool and removing the resistor elements from the carrier plates.

6. The method of making small area, thin-film resistor elements that comprises mixing finely divided resistance material with a temporary binder, applying a thin film of the mixture to a flat plate, removing the film from the plate, cutting the film into pieces of desired shape and area, placing each of the pieces of film on a heat distributing carrier, and heat treating the pieces to form them into dense, self-sustaining resistor bodies.

7. The method of making small area, thin-film resistor elements that comprises mixing finely divided resistance material with a temporary binder, forming a relatively large area, thin film of the material, dividing this film into small pieces, and heat treating the pieces on heat distributing carriers of refractory material to form dense self-supporting resistor elements, said large area film being formed on a flat surface of a temporary backing.

8. The method of making small area, thin-film resistor elements that comprises mixing finely divided resistance material with a temporary binder, applying a thin film of the mixture to a flat plate, dividing the film into sections of the desired shape and area, removing each section from the plate, placing each section of film on a heat distributing carrier, and heat treating the sections to form them into dense, self-sustaining resistor bodies.

JOSEPH A. BECKER.
HOWARD CHRISTENSEN.