May 3, 1966 S. N. KARALIS ETAL 3,249,904

GLASS ENCLOSED CARBON-FILM RESISTOR

Original Filed May 9, 1961

3 Sheets-Sheet 1

Fig. 1.

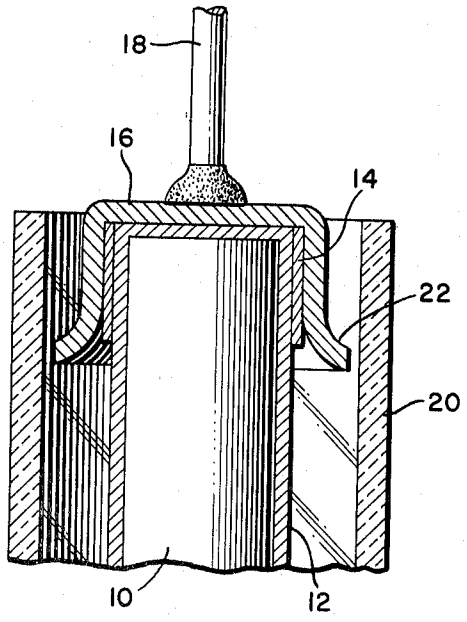


Fig. 2.

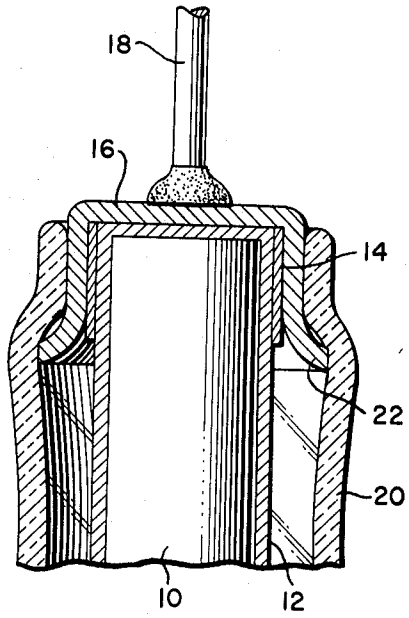
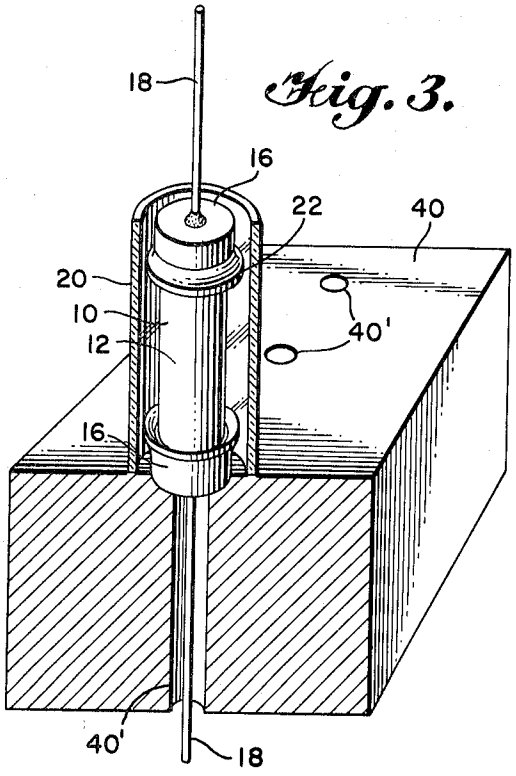


Fig. 3.



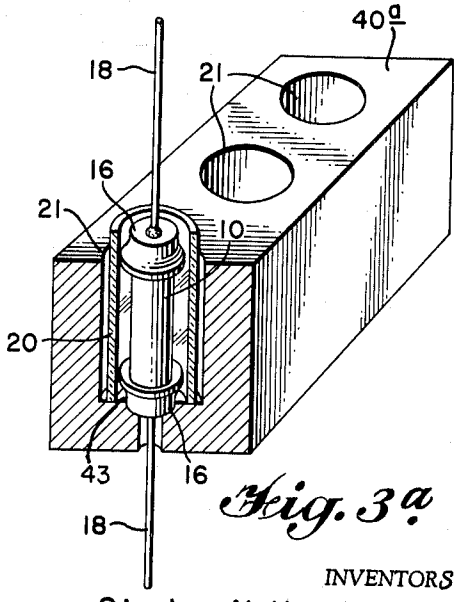


Fig. 3a

INVENTORS

Stephen N. Karalis,
John R. Pies
& Cecil L. Slattum

BY

ATTORNEYS

May 3, 1966 S. N. KARALIS ETAL 3,249,904

GLASS ENCLOSED CARBON-FILM RESISTOR

Original Filed May 9, 1961 3 Sheets-Sheet 2

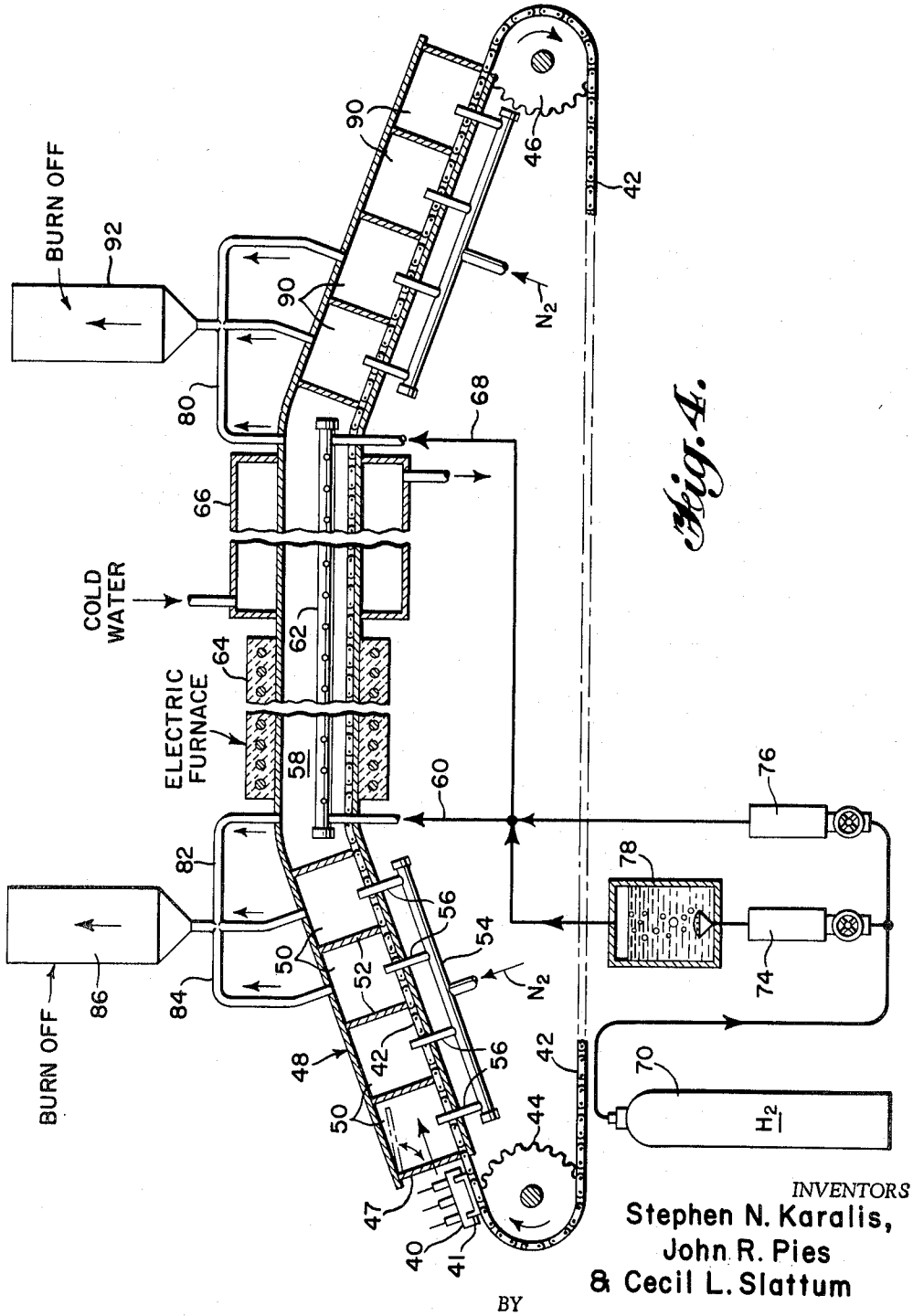


Fig. 4.

INVENTORS
Stephen N. Karalis,
John R. Pies
& Cecil L. Slattum

BY

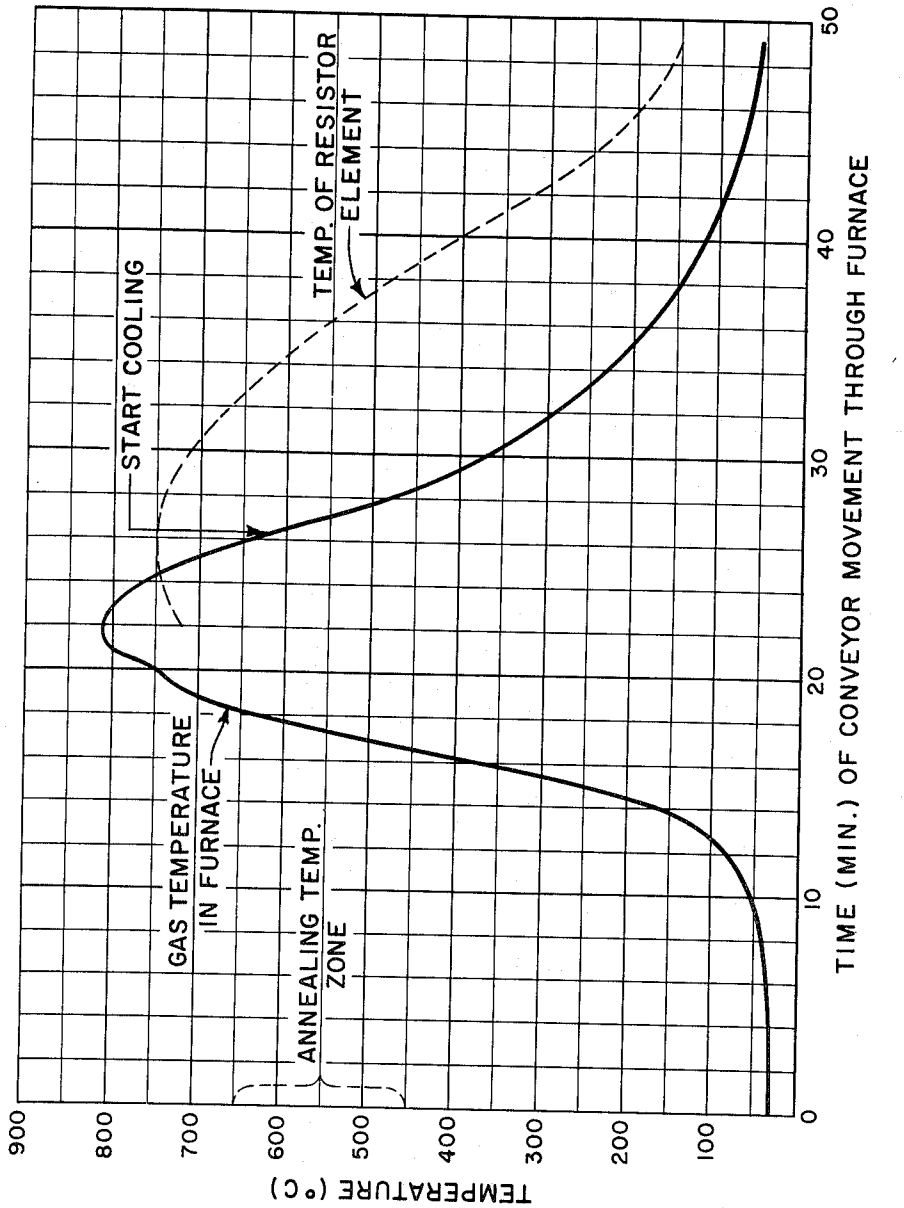
ATTORNEYS

May 3, 1966 S. N. KARALIS ETAL 3,249,904

GLASS ENCLOSED CARBON-FILM RESISTOR

Original Filed May 9, 1961 3 Sheets-Sheet 3

Fig. 5.



INVENTORS

Stephen N. Karalis,
John R. Pies
& Cecil L. Slattum

BY

ATTORNEYS

United States Patent Office 3,249,904 Patented May 3, 1966

3,249,904

GLASS ENCLOSED CARBON-FILM RESISTOR

Stephen N. Karalis, Garland, and John R. Pies and Cecil L. Slattum, Dallas, Tex., assignors to Texas Instruments Incorporated, Dallas, Tex., a corporation of Delaware

Original application May 9, 1961, Ser. No. 108,877, now Patent No. 3,205,562, dated Sept. 14, 1965. Divided and this application Apr. 6, 1965, Ser. No. 445,920

3 Claims. (Cl. 338—237)

This is a divisional of our application, Serial No. 108,877, filed May 9, 1961 now Patent No. 3,205,562. The present invention relates to a novel resistor package and to a unique method for encapsulating resistor elements. More particularly the present invention relates to a resistor package of the carbon-film type resistor and to an improved method for packaging a carbon film resistor to improve its stability and load life.

In the art of resistor manfacturing, it is common practice to produce carbon film resistors for the low price resistor market. To date, the quality of carbon film resistors has been good but not excellent. It has now been discovered that the difficulties involved in producing carbon film resistors of high quality are traceable to the manner of encapsulating the resistor elements. It is common practice to encapsulate the carbon film resistor elements in a glass package. This is normally accomplished in a vacuum chamber wherein the vacuum is of a relatively high order. The purpose of this is to exclude from the resistor package all forms of impurities and, in particular, oxygen which would tend to degrade the carbon film by oxidation and thereby change its resistance value. Normally, glass encapsulation of the resistor element involves placing a glass sleeve about the resistor element and heating them in a vacuum in order to fuse the ends of the glass sleeve to metal caps attached to the ends of the resistance element. During this process, quite frequently, the entire glass sleeve becomes molten and falls against the carbon film. When this occurs an intimate contact is established between the glass enclosure and the carbon film. Prior art attempts to provide a glass enclosure whereby the glass is in intimate contact with the carbon film throughout its area, thereby excluding the presence of any air which contains oxygen, have been unsuccessful. It has been discovered that such construction possesses disadvantages in that the glass is characterized by cracks and pin holes, and therefore oxygen reaches the carbon film. Also the glass can become conductive over a shunt path and shunt out portions of the resistance element.

Consequently the present invention is an extension of the philosophy generally acknowledged by the art that a more advantageous structure is achieved if the glass sleeve which surrounds and encapsulates the resistor core is prevented from coming into contact with it. In a conventional setup, great difficulty is experienced in preventing the glass sleeve from collapsing onto the carbon film during the sealing operation. The essence of this invention is the provision of a means and manner of successfully and reproducibly sealing a glass sleeve to a resistor element without a collapse of the glass sleeve onto the carbon film. This means includes a novel design for the end caps of the resistor element.

The present invention also stems from the knowledge that the electrical terminations employed to contact the carbon film usually contain an organic binder or carrier. Thereafter, it is customary to press fit end caps onto the electrical terminations, and finally seal a glass sleeve to the end caps to complete the enclosure. During the sealing, the high temperatures required drive off the organic binder and produce thermal decomposition resulting in the formation of some carbon, most probably of

an amorphous variety. This carbon, if it deposits upon the crystalline carbon forming the carbon film of the resistor element, will tend to degrade its resistance characteristics. Consequently, care must be taken to remove any carbon deposits formed.

According to the present invention, the above and foregoing is accomplished by the provision of a novel resistor package and a unique method of encapsulating the resistor. The present invention is most particularly concerned with carbon film resistors and a package therefor, and to a method of encapsulating a carbon film resistor, whereby the film resistance element will have stability, longer load life and meet more rigid specifications than carbon film resistors heretofore known.

It is accordingly an object of the present invention to provide a novel carbon film package and a unique method of packaging carbon film resistors which will produce a carbon film resistor superior to those heretofore known and which will be competitive in the low priced resistor market.

Other and further objects of the present invention will become evident from the following description of a preferred embodiment thereof and the best mode contemplated for carrying it out with particular reference to the figures of the drawing wherein:

FIGURE 1 is a view in fragmentary section of a resistor package immediately prior to encapsulation by a glass sleeve;

FIGURE 2 is a similar view in section of a resistor package showing the glass-to-metal seals between the glass sleeve and the end caps of the resistor;

FIGURE 3 is a view in section showing the assembly mounted on a carbon block to be subjected to the heat treatment necessary to accomplish the glass-to-metal seal;

FIGURE 3*a* is a modified form of the carbon block of FIGURE 3;

FIGURE 4 is a schematic representation of the furnace in which the heat treatment occurs; and

FIGURE 5 is a diagram showing the temperature profile of the furnace atmosphere as measured by a thermocouple traveling through the furnace in a resistor carrier.

Referring first to FIGURES 1 to 2, a preferred embodiment of the resistor package will be described in detail. The resistor package consists of an inner ceramic core **10** approximately 0.335 inch long and 0.062 inch in diameter and of cylindrical configuration. The preparation of the ceramic core is conventional in the art. The core is extremely pure and presents a reasonably smooth surface. Coated about the entire surface of the ceramic core **10** is a crystalline carbon film **12**. This also is conventional in the art and consequently no elaborate explanation need be given here as to its accomplishment. Coated around the ends of the ceramic core **10** and carbon file **12** are rings **14** constituting electrical terminations. These rings **14** may be composed of silver, gold, nickel, or graphite and are applied in any way as by painting, sputtering, spraying, or as often applied, in a particulate form with an organic binder or carrier. Thereafter end caps **16** are press fitted onto the ends of the resistor element in intimate contact with the electrical terminations **14**. Welded to the end caps **16** are leads **18** of soft copper. The end cap **16** is composed of a suitable material that has matching thermal properties with reference to the glass to which it is attached. Examples of such material are "Kovar," "Rodar" or "Therlo," trade names for well known iron-nickel-cobalt alloys. A glass sleeve **20** such as Corning Glass Works No. 7052, or other "hard" glass having a thermal expansion coefficient corresponding to the material of the end cap **16**, surrounds the resistor element, and a glass-to-metal seal exists between the ends of the glass sleeve **20** and the end caps **16**. It will be noted that the

end caps **16** are provided with a flared lip designated by the reference numeral **22**. In a specific embodiment the end caps **16** have a diameter of 0.074 inch plus or minus 0.002 inch, and the diameter of the lip of the end cap at the flare **22** is 0.080 inch plus or minus 0.0015 inch. The glass sleeve **20** is slightly larger in internal diameter than the resistor assembly that fits therein. This is visually demonstrable from FIGURE 1 which shows the glass sleeve **20** placed about the resistor assembly prior to forming the glass-to-metal seal between the ends of the glass sleeve **20** and the end caps **16**. The internal diameter of the glass sleeve **20** in the specific example is 0.087 inch plus or minus 0.004 inch. Consequently, the glass sleeve and the end caps **16** will have an average minimum spacing of about 0.001 inch and an average maximum spacing of about 0.005 inch. The space between the film **12** and sleeve **20** is filled with a reducing atmosphere.

Referring now to FIGURES 3 and 4, the method for accomplishing the glass-to-metal seal will now be described in detail. As noted from FIGURE 3, the resistor assembly consisting of the ceramic core, carbon film, terminations and end caps is mounted on a carbon block **40** provided with a hole. The carbon block is approximately 0.4 inch in thickness, and the hole defined therethrough is of a diameter less than the diameter of an end cap. The glass sleeve to be sealed to the end caps is placed about the resistor assembly on the carbon block so that the two parts are arranged in a vertical or upstanding relationship. The carbon block **40** may be arranged with a plurality of other such assemblies on carrier **41**. Block **40** is introduced into a furnace according to the scheme of FIGURE 4. The carbon block **40** is located on a chain conveyor **42** which passes over sprocket wheels **44** and **46**, one of which is driven by a motor in such a manner that the carbon block **40** and carrier **41** pass through a furnace assembly. The entry to the furnace assembly is designated by the reference numeral **47**, and the first section **48** of the assembly comprises a series of locks **50** defined by swinging doors generally designated by the reference numeral **52**. A manifold **54** into which is fed nitrogen gas is connected by means of short pipes **56** with each of the locks **50**. The exit from the last lock **50** leads into a furnace chamber designated by the reference numeral **58**. The furnace chamber is surrounded by a muffle type heating element **64** such as a ceramic block containing embedded resistance wire. A pipe **60** is connected to the furnace chamber for the purpose of introducing hydrogen gas into the main furnace chamber. Pipe **60** interconnects with a manifold **62** that extends the length of the furnace chamber **58**. It will be noted at this point that the furnace chamber **58** is divided into two parts as shown in FIGURE 4. The heater **64** surrounding the left hand part of the furnace chamber **58** is the muffle type heater previously described. A cold water jacket **66** surrounds the right hand side of the furnace chamber **58** and is provided with a suitable inlet and outlet for cold water.

The manifold **62** extends the entire length of the furnace chamber **58** and is connected at its extreme right-hand end with a pipe **68** also for the purpose of admitting hydrogan to the manifold. The pipe **68** and pipe **60** join and are fed by two streams. A main supply **70** of purified hydrogen passes via pipe **72** through two flow meters **74** and **76**. Approximately 10% of the flow in the pipe **72** passes through the meter **74**, and the remaining 90% passes through the meter **76**. The portion passing through the meter **74** is bubbled through a water bottle **78**, thereby entraining a certain amount of water vapor. The water in the bottle **78** is maintained at ambient conditions. Thereafter, the two streams of hydrogen are recombined at the junction of pipes **60** and **68**. Therefore, the hydrogen entering the manifold **62** at opposite ends is of the same consistency, containing a slight amount of water vapor. Exit pipes **80** and **82** are provided from the chamber **58** also at opposite ends. Also, exit pipes **84** are provided from the last two locks **50** and combined with the hydrogen exhaust in line **82** and sent to a burn-off designated by the reference numeral **86**. The arrangement at the far end of the furnace is exactly the same in that four locks **90** are provided, each separated by means of swinging doors, and nitrogen is admitted via a manifold into the four locks. The exhaust from the two locks closest to the furnace chamber **58** are combined with the exhaust in pipe **80** and sent to a burn-off **92**.

The profile of the temperature in the furnace is shown in FIGURE 5 with relation to both elapsed time and the movement of a carbon block **40** therethrough. The solid line in FIGURE 5 designates the gas temperature in the furnace **58**, whereas the dotted line in FIGURE 5 represents the temperature of the resistor element in the furnace. It will be noted that the resistor element temperature lags behind the gas temperature during the movement of the resistor element through the furnace. This is an important consideration. The exact time and temperatures are listed in the following table and are the ones utilized in the drafting of the temperature profile shown in FIGURE 5.

Temperature profile 14' furnace

[Chain speed 3.43 in./min.; controller temperature 850° C; H_2 12.5 c.f.h.; wet H_2 2.5 c.f.h.; N_2 40 c.f.h.]

Travel Location Points	Time (Min.)	Temperature (Furnace atmosphere), ° C.
Block and Carrier entering first door		30
	1	30
	2	30
	3	30
First door on entrance side close		30
	4	31
	5	31
	6	31
		34
	7	36
	8	39
	9	42
	10	56
Last door (on entrance side) close		58
	11	67
	12	82
	13	105
	14	156
	15	252
	16	376
	17	506
	18	623
	19	712
	20	748
	21	803
Peak furnace temperature		812
	22	812
	23	798
	24	767
	25	715
	26	640
	27	561
	28	481
	29	419
	30	365
	31	330
	32	292
	33	260
	34	232
	35	206
	36	183
	37	164
	38	147
	39	132
	40	118
	41	107
First door (on exit side) open	42	100
	43	92
	44	83
First door (on exit side) close	45	74
	46	67
	47	63
	48	59
	49	56

The purpose of the water vapor entrained in the hydrogen gas is to take care of carbon produced by thermal-decomposition of any organics that may be present in the resistor package. The obvious source of organics is the binder employed in the electrical termination, and the water vapor serves to oxidize the amorphous carbon formed. The hydrogen atmosphere is necessary to pre-

vent degradation of the carbon film during the encapsulation in the glass sleeve.

During the pass through the furnace, the resistor assembly will be heated. The end caps, being metal, will heat more quickly than the remaining parts. Because the lips of the end caps are flared, they will be closer to the glass sleeve than any other part of the assembly. Consequently the annular portions of the glass sleeve radially aligned with the flared lips of the end caps will become softened first and drawn onto the flared lips of the end caps. The glass will wet the metal caps, and gradually the end portions of the glass sleeve will go from the condition shown in FIGURE 1 to that shown in FIGURE 2. The end caps cannot be oxidized to form a good metal-to-glass seal as the art suggests, because the sealing is carried out in a reducing atmosphere. Therefore, the end caps are roughened by sand blasting prior to assembly.

The glass-to-metal seals occur before the center section of the glass sleeve softens and falls against the carbon film. Since the heating takes place with the parts arranged vertically, the sleeve may sag and bow in slightly, but it does not touch the carbon film. As is readily noted, a reducing atmosphere is sealed within the sleeve.

From the temperature profile of FIGURE 5 it can be seen that the gas temperature (solid line) in the furnace leads the temperature of the assembly (broken line). The glass temperature never quite reaches the peak furnace temperature, as the gas temperature falls off rapidly. The assembly temperature follows a more gradual slope. This is significant as the annealing temperature range for the glass sleeve is from about 450° C. to about 650° C. As can be determined from FIGURE 5, it takes about six minutes to drop the temperature of the glass sleeve through this range. Therefore, the glass cools at a relatively slow rate, about 33° C. per minute, and subsequent tests show the glass stress to be about 150 lbs./square inch average.

The carbon block or boat **40***a* shown in FIGURE 3*a* is a modified boat which is used in a similar manner to block or boat **40** for larger size resistor elements. In this boat (**40***a*) the glass sleeve **20** is inserted in a circular recess **21** in such a manner that both ends of the sleeve are exposed to the furnace atmosphere, but the central portion of the sleeve is shielded by the main body of the block **40***a*. A ledge **43** supports both the sleeve and resistor element during their movement through the furnace. Both carbon blocks **40** and **40***a* are supported on a metal frame carrier **41**, which in turn is supported on the traveling chain conveyor **42**, so that the conveyor, carriers and blocks all move simultaneously through the furnace. While the furnace heater **64** is set to provide a maximum furnace atmosphere temperature of 812° C. inside the furnace, this temperature will not be uniform throughout the length of the furnace (as shown in the temperature profile curves of FIGURE 5) due to the fact that the doors at each end of the furnace admit cooler atmosphere when the individual resistor elements are entering and leaving the furnace. The temperature of the furnace atmosphere was measured by a thermocouple which was substituted for one of the resistor elements and traveled through the furnace on one of the carbon blocks or boats **40** (or **40***a*). The temperature of the resistor elements was measured by a thermocouple located adjacent the carbon film **12** and inside the glass sleeve **20**.

Although the present invention has been shown and described with respect to preferred embodiments, various changes and modifications will occur to those skilled in the art which do not depart from the spirit, scope and contemplation of this invention. Accordingly, said changes and modifications are deemed to come within the purview of the teachings and concepts of this invention as defined by the appended claims.

What is claimed is:

1. A glass enclosed resistance package comprising in combination a resistance element, a metal member attached to each end of said resistance element and sealed thereto, each of said metal members having a flared end portion, and a glass element enclosing said resistance element and extending over the flared portion of each of said metal members and sealed thereto, said flared portions of said metal members holding said glass element away from said resistance element.

2. A glass enclosed resistor package as defined in claim **1** wherein each of said metal members has a sand-blasted finish.

3. A glass enclosed resistance package comprising in combination a cylindrical resistance element, a conductive ring around each end of said cylindrical resistive element, a metal member on each end of said resistor element positioned over said conductive element and in electrical contact therewith, each of said metal members having a flared end portion, and a glass element enclosing said resistance element, said glass element extending over the flared portion of each of said metal members and sealed thereto, said flared portions of said metal members holding said glass element away from said resistance element.

References Cited by the Examiner

UNITED STATES PATENTS

977,268	11/1910	Bucsko.	
2,332,255	10/1943	Podolsky	338—235
2,405,449	8/1946	Robinson et al.	338—237 X
2,416,599	2/1947	Victorsen	338—237
2,547,405	4/1951	Mitchell et al.	338—237 X
2,635,162	4/1953	Kohring	338—237 X
2,697,805	12/1954	Collins	65—59 X
2,930,018	3/1960	Hinkle	338—237
2,977,561	3/1961	Pugh et al.	338—237

FOREIGN PATENTS

510,363	2/1955	Canada.

RICHARD M. WOOD, *Primary Examiner.*

V. Y. MAYEWSKY, *Assistant Examiner.*