United States Patent

[11] 3,576,066

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[54] **METHOD OF MAKING VACUUM COMPONENTS**
9 Claims, 9 Drawing Figs.

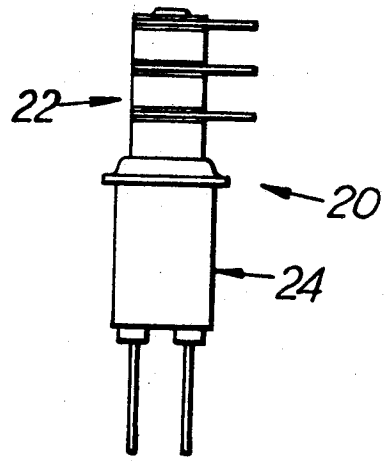
[52] **U.S. Cl.** **29/494,** 29/497, 316/18, 316/19, 316/21
[51] **Int. Cl.** **B23k 31/02,** B23k 35/38
[50] **Field of Search** 29/494, 497, 487; 316/18, 19, 21

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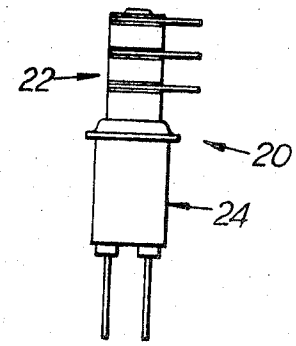
ABSTRACT: A method of making evacuated enclosures such as envelopes for vacuum switches, relays, or interrupters. The method may include a step of brazing the envelope to provide an hermetic seal in a reducing atmosphere at atmospheric pressure. The envelope is then reheated in a vacuum chamber. At least one portion of the envelope is made of a material through which the reducing gas can pass.



PATENTED APR 27 1971 3,576,066

SHEET 1 OF 3

Fig. 1.



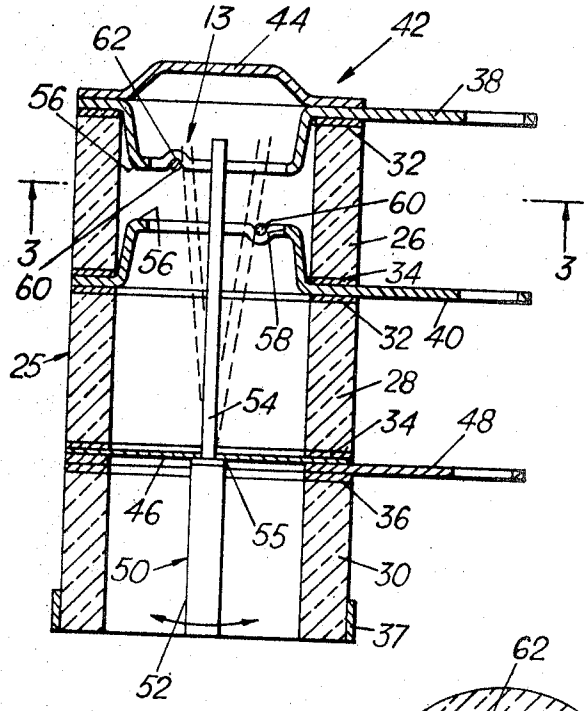
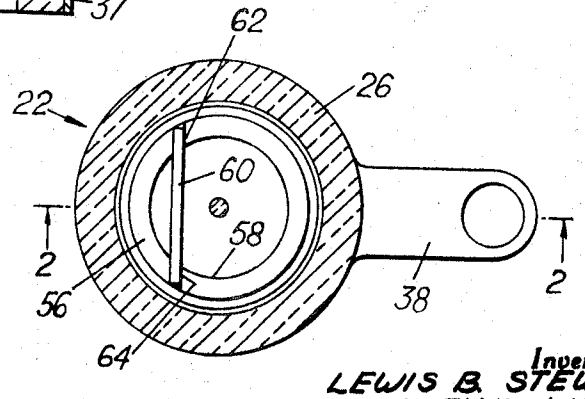


Fig. 2.

Fig. 3.



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Fig. 4.

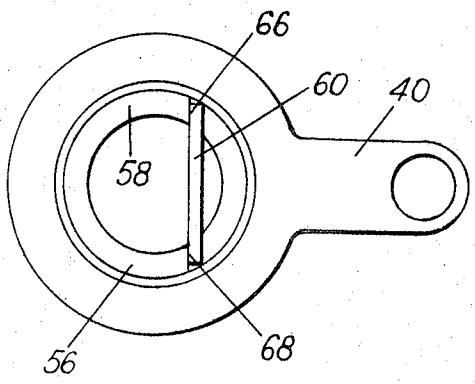
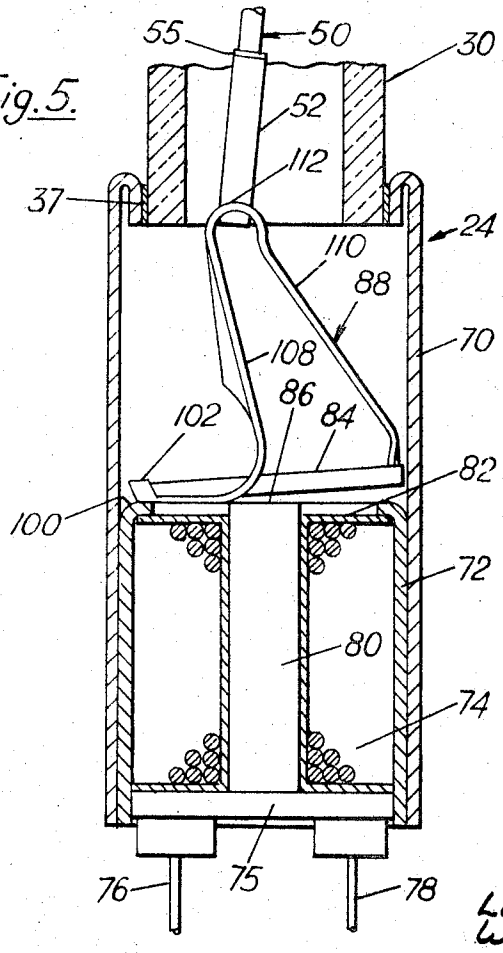


Fig. 5.



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Fig. 6.

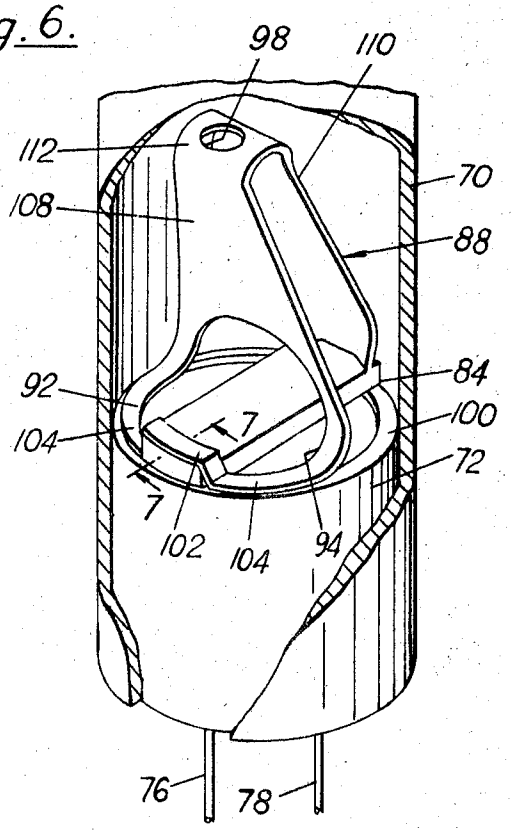


Fig. 8.

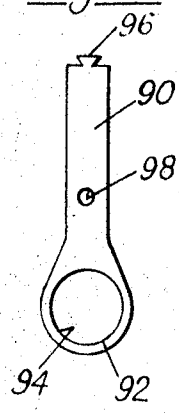


Fig. 7.

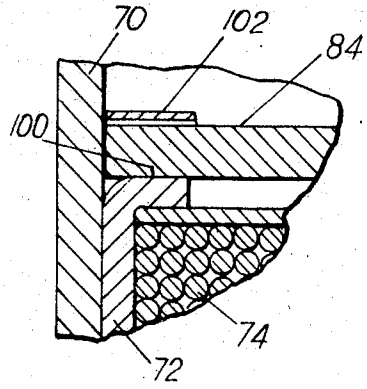
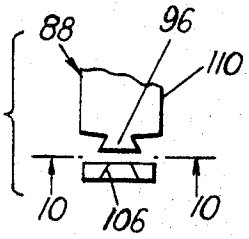


Fig. 9.



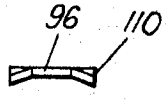


Fig. 10.

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METHOD OF MAKING VACUUM COMPONENTS

BACKGROUND OF THE INVENTION

This invention relates to evacuated enclosures and, more particularly, to an improved method of withdrawing a gas from the interior of an envelope.

Although the method of the present invention will have a large scope of application and should thus not be limited to the specific uses set forth herein, the invention has been found to possess exceptional utility in making vacuum switches, vacuum relays, and vacuum interrupters.

In the past, it has been the practice to outgas an envelope by heating it in a vacuum chamber. That is, the envelope is heated, and the gasses therein and therearound are pumped out at the same time. When the desired vacuum level is reached, the envelope is sealed by brazing or otherwise.

Due to the fact that the envelope must be heated while it is inside the vacuum chamber, induction heaters must often be used. Although possible to manufacture large quantities of evacuated envelopes in this way they must be aligned with the induction heaters. Therefore, the prior art method is expensive. In the prior art, it has also been difficult to keep the parts of a vacuum component completely free of surface oxides so as not to interfere with the operation thereof.

SUMMARY OF THE INVENTION

In accordance with the method of the invention, the above-described and other disadvantages of the prior art are overcome by withdrawing gas from inside an envelope after the envelope has been hermetically sealed. In this case, the envelope is provided with at least a portion through which the gas will penetrate.

In accordance with one feature of the invention, the envelope is brazed (hermetically sealed) in a reducing atmosphere at atmospheric pressure. The reducing atmosphere keeps the component parts clean. Further, conventional resistance heaters may also be economically used for heating a large number of envelopes simultaneously at the convenient pressure of 1 atmosphere. The same large number of envelopes may then be economically heated by resistance heaters and evacuated in a vacuum oven. Moreover, the said large number all may be heated and evacuated at the same time. Thus, by processing the envelopes more or less in batches, production is increased and costs are lowered.

The above-described and other advantages of the invention will be better understood from the following description when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a side elevational view showing in actual size a relay upon which the present invention may be practiced, the relay including both a switch portion and an actuating assembly;

FIG. 2 is an enlarged longitudinal sectional view, partly in elevation, through the central axis of the switch portion of the relay illustrated in FIG. 1, the plane of the section being indicated by line 2–2 in FIG. 3;

FIG. 3 is a transverse sectional view taken along line 3–3 of the switch portion of FIG. 2;

FIG. 4 is a top plan view of one of the fixed contact assemblies shown apart from the remainder of the switch structure;

FIG. 5 is a longitudinal sectional view, partly in elevation, through the central axis of the actuating assembly of the relay illustrated in FIG. 1;

FIG. 6 is a perspective view of the coil, armature, and resilient bracket employed in the actuating assembly illustrated in FIG. 5;

FIG. 7 is an enlarged fragmentary vertical section taken along line 7–7 in FIG. 6 showing the pivotable mounting construction of the armature;

FIG. 8 is a top plan view, on a reduced scale, of a sheet metal blank which is bent into the form of a bracket utilized for mounting the armature in the actuating assembly;

FIG. 9 is an exploded view showing in plan the end of a resilient bracket and the free end of the armature to which the end of the bracket is connected; and

FIG. 10 is a sectional view taken along line 10–10 in FIG. 9 showing in elevation the free end of the resilient bracket.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the drawings, in FIG. 1, there is illustrated a relay 20 upon which the present invention may be practiced. Relay 20 includes an upper switch portion 22 and a lower actuating assembly 24. As best seen in FIG. 2, the switch portion 22 of the relay includes an envelope 25 composed of two axially aligned, elongated tubular insulator envelope sections 26 and 28, preferably formed of ceramic. A third ceramic tubular section 30 is provided for connecting the switch envelope to the actuating assembly 24. The ceramic sections 26 and 28 are provided at their remote ends with metallized edges 32 and 34 while the ceramic section 30 has its upper end metallized as indicated at 36 and its lower outer periphery metallized as indicated at 37. A first annular metallic terminal electrode 38 is hermetically brazed to the metallized edge 32 of the ceramic section 26 while a second annular metallic terminal electrode 40 is hermetically brazed to the lower metallized edge 34 of the ceramic section 26. The metallized upper edge 32 of ceramic section 28 is brazed to the lower surface of the terminal electrode 40.

A metallic end cap 42 is brazed to the upper surface of the terminal electrode 38 and closes the upper end of the switch envelope. Preferably the end cap 42 is provided with an upwardly extending, domed portion 44. It is to be noted that this end cap assembly eliminates an appendage which constitutes a tubulation employed in prior art relays, thus reducing the cost and complexities of production. End cap 42 is preferably made of nickel or nickel-iron according to the method of the present invention. However, in accordance with the invention, nickel may be used by itself.

Nickel is used because, as will be explained, the switch portion 22 shown in FIG. 2 is brazed in a hydrogen oven. Hydrogen is, thus, sealed inside the switch portion. This hydrogen must be removed to create a high vacuum. The hydrogen left inside may, in fact, be removed by diffusing it through portion 44 at an elevated temperature. This is true because nickel and nickel-iron may be penetrated by hydrogen gas at elevated temperatures.

A relatively thin metallic diaphragm 46 is hermetically brazed to the lower metallized edge 34 of the ceramic section 28. A third terminal electrode 48 is interposed between the upper metallized edge 36 of the ceramic section 30 and the lower surface of the metallic diaphragm 46. This electrode provides a terminal for the actuator rod 50.

The diaphragm 46 is sufficiently flexible to permit transverse pivotal movement of the longitudinally extending actuator rod. The rod is provided with a lower ceramic contact end 50 extending toward the actuating assembly 24, while the upper end 54 of the actuator rod extends through a central aperture formed in the flexible diaphragm 46 and is hermetically brazed thereto. The upper surface of the ceramic contact end 52 is metallized as indicated at 55 and brazed to the diaphragm 46. The terminal electrodes 38, 40 and 48 are preferably formed of copper to provide a high current-carrying capacity while the actuator rod 50 is formed of a metal which is substantially harder than the terminal electrodes so that it will not bend from impact with the terminal electrodes.

The terminal electrodes 38 and 40 are conveniently formed from sheet copper stamped into the configuration desired. As shown, the preferred configuration is one in which the portions of the terminal electrodes 38 and 40 within the ceramic envelope are dished toward each other as indicated at

56. The circular openings 58 in the annular terminal electrodes are disposed within the dished portion 56 thereof and are coaxial with the longitudinal axis of the switch envelope.

Relatively rigid, small, straight metal contact wires or rods 60 are provided on the terminal electrodes. Rods 60 have substantially the same hardness as the actuator rod and, hence, substantially greater hardness than that of the terminal electrodes. Preferably, the actuator rod and contact rods are formed of refractory metals, such as titanium, tungsten, or molybdenum or of base metals such as iron, chromium, nickel, or alloys thereof. These materials are substantially harder than the copper terminal electrodes. Also, it is preferable that the actuator rod be formed of a metal different than the metal of the contact rods so that welding of the rods will not occur upon continued impact therebetween.

One of the wires 60 is pressed into aligned grooves 62 and 64 in the lower surface of the dished portion 56 of electrode 38. The other wire 60 is pressed into aligned grooves 66 and 68 in the top surface of the dished portion of the electrode 40. The pairs of grooves in each of the electrodes 38 and 40 are preferably aligned and so arranged that the wire contacts 60 are parallel to each other and form cords across the circular openings 58 in the electrodes. Preferably, the rods 60 are disposed so that the movement of the pivoted actuator rod is normal to the contact rods to insure firm contact therebetween.

The wires 60 may be mounted on the dished portions of electrodes 38 and 40 by forming the grooves initially in the electrodes and forcing the wires therein. Alternatively, a die having appropriately arranged grooves may be placed in the dished portion of the electrodes so that upon pressing the wire contacts against the opposite side of the electrodes toward the die grooves, grooves will be formed in the electrodes simultaneously with securing the wires therein. With either method, the contact rods can be accurately located in any predetermined position depending upon the spacial relationship desired between the rods. Also, the rods can be positioned in exact parallel relationship so that there is a uniform gap between the two fixed contact surfaces. If desired, after the contact rods are pressed into the terminal electrodes, they may be brazed at the point of contact with the electrodes although this is not essential.

It can be appreciated that substantial latitude is available at the time of assembly as to the material of the fixed contacts which will be provided in the relay, i.e., contact rods formed of any one of the metals mentioned herein may be utilized and without requiring the use of entire terminal electrodes of different materials.

During the manufacture of relays, depending upon how the method of the invention is used, it is sometimes possible by the prior method that an oxidation film will form on the contact rods, thus increasing the contact resistance of the relays. Thus, if desired, a coating of metal may be provided on the rods. The coating may have a higher electrical and thermal conductivity than that of the rods per se. Examples of metals for the coating are copper and noble metals, such as gold and silver, which are applied to the contact rods prior to assembly thereof to the terminal electrodes. The coating may be applied by electrodeposition, vapor deposition, or sputtering techniques. The coating may have a thickness of only a few atoms to about 0.005 inch to maintain the contact resistance of the relay at a minimum, yet still take full advantage of the hardness of the base contact rod material to minimize deformation of the contact rods when contacted by the actuator rod. Even though the coating is itself subject to deformation when contacted by the actuator rod, since the coating is quite thin, such deformation is only slight. Moreover, since the coating material is highly malleable, it tends to flow and, therefore, fill up any deformed surface area. This invention removes the requirement for coating the rods, thereby reducing the number of operations required to produce a low contact resistance relay.

Summarizing, straight wire contacts 60 are rigid and parallel. They also are formed of a material having substantially the same hardness as that of the actuator rod 54 so that upon contact of the actuator rod with the contact rods, a minimum amount of deformation of the materials results with a resultant minimum degree of variation in the electrical characteristics of the relay over extended use of the relay. Furthermore, since the metal wires 60, present fixed, straight, generally parallel, opposed contact surfaces, there will be no variation in the electrical characteristics of the relay even if the path of movement of the actuator rod varies in a direction parallel to such rods. Also, because the wire contacts 60 are mounted on the dished portions of the electrodes 38 and 40, the contacts are spaced axially apart in a relatively short distance, thus minimizing the amount of pivotal movement required for the actuator rod 50 to engage the contact wires. In addition, the dished portions 56 of the electrodes 38 and 40 serve as shields to obstruct any vaporized metal which might be produced by the actuator rod 54 striking the contact wires 60 from impinging upon the inner surfaces of the ceramic sections 26 and 28. Finally, the electrodes 38 and 40 are of identical form, except for the location of the contacts 60, thus reducing the number of different parts required in the manufacture of the relay. The small rods 60 are easily manufactured by merely cutting proper lengths of wire.

Reference is now made to FIGS. 5 through 10 which show in detail the construction of the actuating assembly 24 for the actuating rod 50. The assembly 24 includes a tubular metallic casing 70 which is coaxial with the tubular switch portion 22 of the relay and is brazed at its upper end to the metallized portion 37 of ceramic section 30. A housing 70, within which is supported an electromagnetic coil 74, is positioned at the lower portion of the casing 70 and retained therein by a disc 75. Terminals 76 and 78 extending through the disc 75 are provided for connecting the coil to a source of electrical power. The coil surrounds a core 80 which is coaxial with the longitudinal axis of the tubular casing 70 and extends upwardly through the upper end 82 of the housing 72.

An armature 84 is positioned above the housing 72 and extends across the upper end 86 of the core. A resilient bracket, generally designated 88, pivotally mounts the armature 84 within the casing 70 and biases the armature upwardly, that is, in a direction opposite to the force applied by the coil 74 when energized.

The bracket 88 is formed from a sheet metal blank 90 having the configuration shown in FIG. 8. The blank 90 has a circular end 92 in which a circular cutout 94 is provided. The other end of the blank 90 is provided with an outwardly flared tab 96. Intermediate the two ends of the blank is an opening 98.

The housing 72 is bent inwardly at the upper end to provide an annular flange 100. The blank 90 is bent into the configuration shown in FIGS. 5 and 6 with an upwardly bent portion 102 of the circular end 92 extending over the upper surface of one end of the armature 84 retaining the same in relatively fixed position, yet with sufficient spacing being provided between the two parts to permit upward pivotal movement of the armature 84 in the casing 70. The portions 104 of the circular end 92 of the bracket on opposite sides of the upwardly extending section 102 are secured by means of brazing or welding to the flange 100.

The outwardly flared tab 96 on the opposite end of the bracket 88 is fitted into a complementary shaped slot 106 at the end of the armature 84 opposite that which is engaged under the circular end 92 of the bracket, as best seen in FIG. 9, thereby providing a fixed connection between the free end of the armature and the bracket.

The bracket is bent upwardly to provide generally vertical legs 108 and 110 which meet at an upper end 112 in which the opening 98 is provided. The lower end 52 of the actuator rod 50 is slidably positioned in the opening 98, thereby providing a lost-motion connection between the actuator rod and the bracket 98.

The resilient pressure asserted by the bracket **88** retains the armature **84** in the position illustrated in FIG. **5** wherein the armature is spaced from the end **86** of core **80**. Upon energization of the coil **74**, the magnetic field generated thereby attracts the armature down against the resilient force asserted by the bracket **88** so that the end **86** of the core **80** is abutted by the armature. During the downward movement of the armature, the upper portion **112** of the bracket **88** will shift in the rightward direction as viewed in FIG. **5**, thereby pivoting the actuator rod about its fulcrum provided by the diaphragm **46**.

As can best be seen, the actuating assembly **24** is of extremely simple construction, requiring only a single metal element, namely the resilient bracket **88**, for both pivotally mounting the armature **84** and for providing a lost-motion connection with the actuator rod **50** for shifting the latter.

According to the method of the present invention, only the switch portion **22** of the relay **20** shown in FIG. **2** need be processed as follows. Actuating assembly **24** need not be so processed.

According to the method of the invention, all the component parts of switch portion **22** shown in FIG. **2** may be stacked or jigged or both before they are hermetically sealed together. Certain components may be fixed together before the final sealing step, if desired. Final sealing may be accomplished by brazing the parts to be brazed in a conventional oven containing hydrogen gas. The gas, thus, surrounds the assembled parts of switch portion **22** and also fills the space inside switch portion **22** along its entire axial length. The pressure of the hydrogen is 1 atmosphere. There is, thus, no need for a vacuum pump at this point and brazing may be done easily and quickly simply by raising the oven temperature to a conventional brazing temperature for a conventional brazing compound.

Preferably, the hydrogen oven has a dewpoint of less than −70° F. The hydrogen oven preferably should be as dry as possible and at least sufficiently dry to prevent an unwanted amount of water vapor from being irretrievably sealed off inside the switch portion **22**. Water vapor sealed inside the switch portion **22** generally will not penetrate end cap **42**, at least within a reasonable time at practical temperatures and pressures.

Due to the fact that brazing is performed according to the method of the present invention at an elevated temperature and at atmospheric pressure, the hydrogen in the interior of switch portion **22** will be below atmospheric pressure if it is allowed to cool to room temperature. The pressure may drop to, for example, one-third of 1 atmosphere.

After the brazing step has been performed, the hydrogen-filled switch portion **22** is preferably placed in a conventional vacuum oven and heated to 700° C. for 45 minutes. The pressure around the outside of switch portion **22** at the same time may, for example, be reduced to 10^{15} Torr although it is preferably reduced to between about 10^{16} Torr and 10^{18} Torr for about 45 minutes. The time during evacuation is, by no means, critical and may be more or less than 45 minutes depending upon to what pressure it is desirable to evacuate switch portion **22** and what temperature is employed.

After evacuation, switch portion **22** may be cooled to room temperature. It is then ready for use.

Hydrogen gas need not necessarily be employed during brazing, although hydrogen is preferred. For example, carbon monoxide may be employed. However, end cap **42** is preferably made of iron if carbon monoxide is employed.

Nickel-iron in proportions of 1:1 by weight is preferably employed for end cap **42** when hydrogen is used.

Hydrogen has the most rapid diffusion rate (increasing production) through palladium. Palladium may also be used for end cap **42** or for a smaller window, if desired. With hydrogen, end cap **42** may also be made of nickel-copper or pure iron. Nickel-iron, nickel-copper, and pure iron have hydrogen diffusion rates of the same order of magnitude, i.e., from 10 to 100 percent that of nickel. Nickel has about the highest hydrogen diffusion rate, except for palladium.

The carbon monoxide diffusion rate through iron is about 1 percent of the diffusion rate of hydrogen through nickel.

The invention is, thus, not limited to the use of hydrogen. Further, the invention is not limited to the use of any specific brazing or evacuation times or temperatures or pressures. Further, the invention is not limited to any particular pressure inside switch portion **22**.

The invention is also not limited to the use of one particular set of materials.

In accordance with the foregoing, it will be appreciated that it is an outstanding advantage of the method of the present invention that a large number of switch portions identical to switch portion **22** may be cleanly brazed simultaneously. The same large number may also be evacuated simultaneously. A substantial increase in production may, thus, be achieved without a corresponding increase in cost.

We claim:

1. The method of making an evacuated enclosure, said method comprising the steps of: hermetically sealing an envelope with a gas inside thereof, said envelope having at least one portion through which said gas will diffuse; and reducing the pressure of gas around the outside of said envelope at least at said portion to a pressure sufficiently below that inside said envelope to cause said gas inside said envelope to diffuse through said envelope portion.

2. The invention as defined in claim **1**, wherein said envelope includes at least two component parts, said sealing step including brazing said parts together in an atmosphere of hydrogen gas at a brazing temperature, the gas left inside said envelope thereby being hydrogen, said brazing step being performed in a hydrogen oven with a dewpoint of less than −70° F., placing said envelope in a vacuum oven, increasing said vacuum oven temperature to about 700° C. for about 45 minutes, reducing the pressure in said vacuum oven to between about 10^{16} to 10^{18} Torr during said 45 minutes.

3. The invention as defined in claim **2**, wherein said envelope portion is made of nickel.

4. The invention as defined in claim **2**, wherein said envelope portion is made of two uniformly mixed metals, said metals being nickel and iron.

5. The invention as defined in claim **1**, wherein said envelope is hermetically sealed at atmospheric pressure in a reducing atmosphere at a temperature above room temperature, said method including the step of heating said sealed envelope and the gas therein at the same time the pressure of the gas therearound is reduced.

6. The invention as defined in claim **1**, wherein said envelope is hermetically sealed in a reducing atmosphere.

7. The invention as defined in claim **1**, wherein said envelope is sealed at atmospheric pressure.

8. The invention as defined in claim **1**, wherein said sealing step is performed at a temperature above room temperature.

9. The invention as defined in claim **1**, wherein said method includes the step of heating said sealed envelope and the gas therein at the same time the pressure of the gas therearound is reduced.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,576,066 Dated April 27, 1971

Inventor(s) Lewis B. Steward et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 54, "10^{15}" should read -- 10^{-5} --; line 55, "10^{16}" and "10^{18}" should read -- 10^{-6}--, and -- 10^{-8} --, respectively. Column 6, line 44, "10^{16}" and "10^{18}" should read -- 10^{-6} --, and -- 10^{-8} --, respectively.

Signed and sealed this 31st day of August 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER,
Commissioner of Pate