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Walker, Sr.

[11] **3,735,024**

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[54] **HIGH-PRESSURE AND HERMETIC ELECTRICAL FEED-THROUGH APPARATUS**

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[52] **U.S. Cl.** .....**174/151,** 29/472.9, 29/592, 174/50.55, 174/50.61, 174/152 GM, 287/189.365

[51] **Int. Cl.** **H01b 17/26,** C03c 27/02

[58] **Field of Search**.....174/18, 50.55, 50.56, 174/50.58, 50.61, 50.63, 151, 152 E, 152 GM; 287/189.365; 29/592, 472.9

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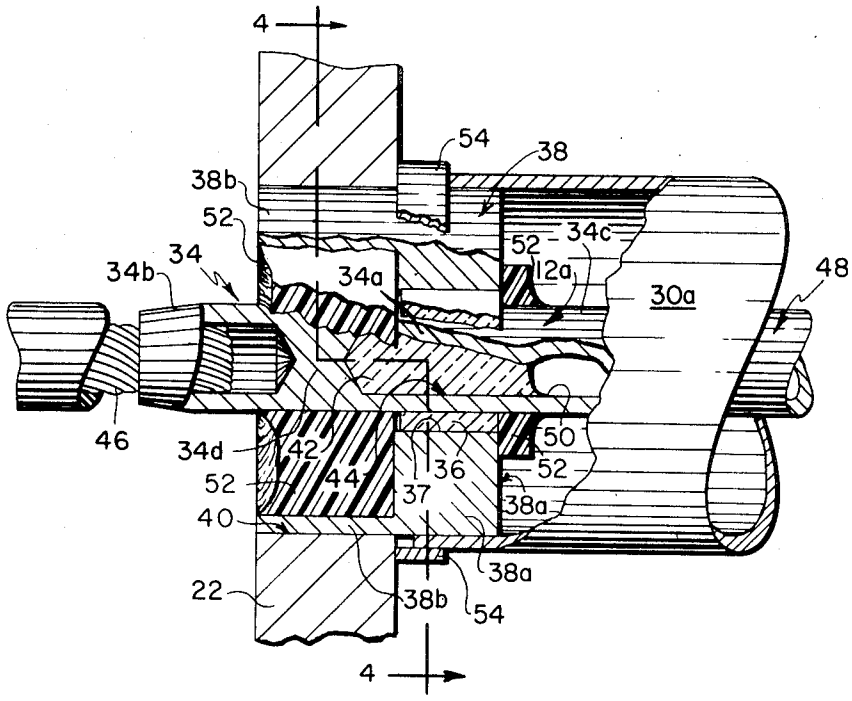
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[57] **ABSTRACT**

A leak-proof and pressure-tight seal at the passage of an electrical current conductor through a wall employs an electrical conductor which is tubular and contains therein a core of hard material having a low coefficient of thermal expansion. A collar-like electrically insulating member encircles the conductor about the core and radially compresses the conductor inward onto the core. The insulating member is seated in the conductor-passing aperture in the wall and the wall exerts significant radial compression onto the collar-like member to compress it firmly against the tubular conductor. Further, the cross-sectional area of the conductor around the core is not substantially less than, and preferably is at least equal to, the cross-sectional area of the conductor elsewhere along its length.

19 Claims, 5 Drawing Figures



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SHEET 1 OF 2

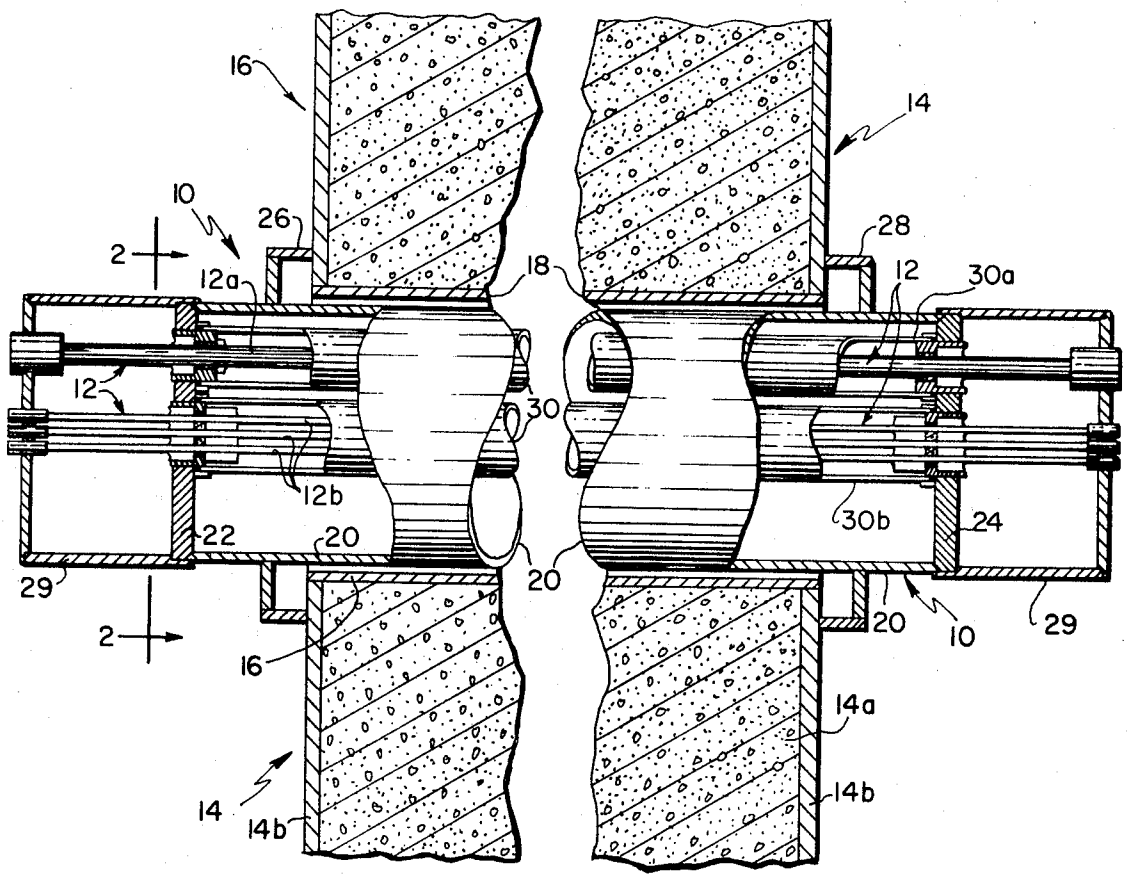


FIG. 1

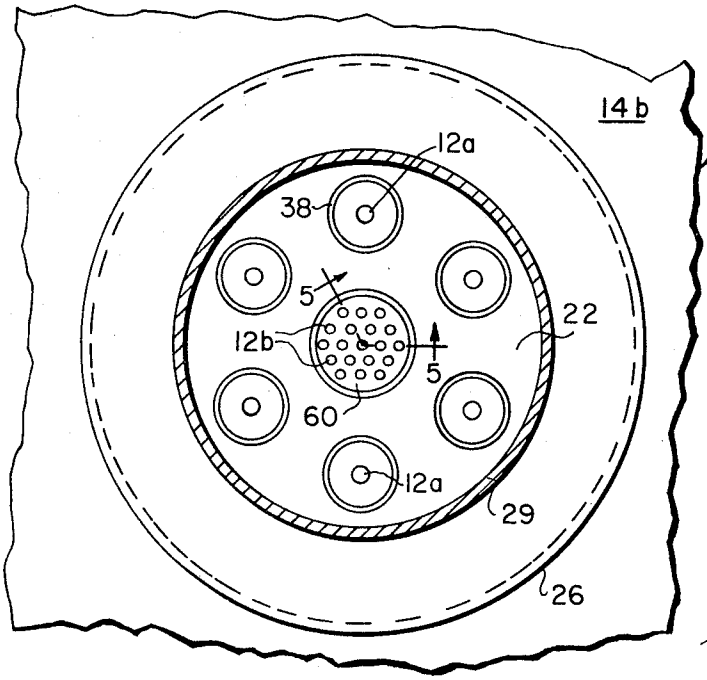


FIG. 2

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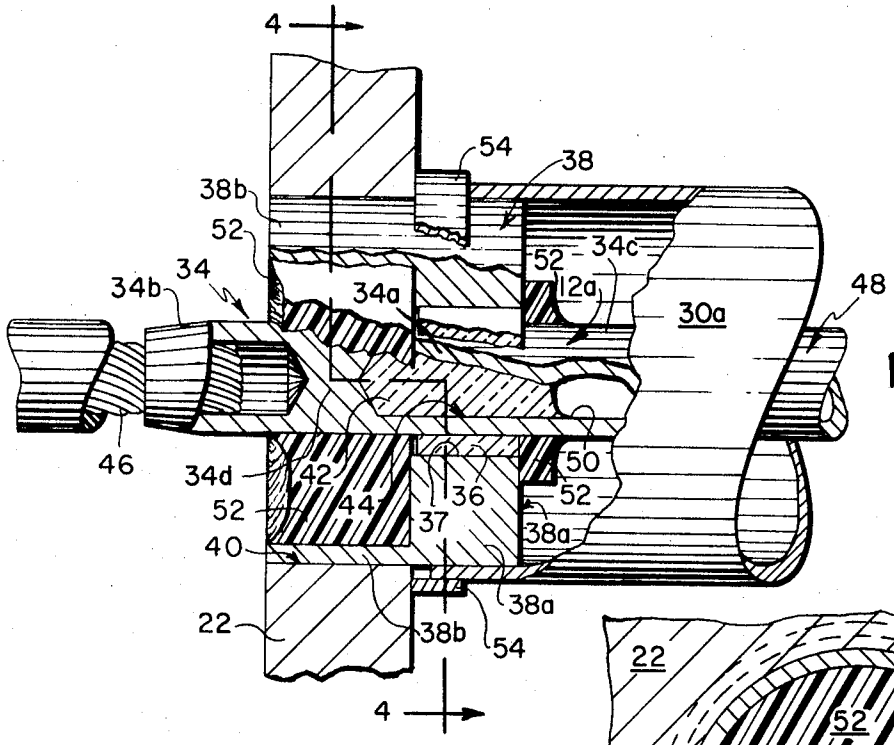
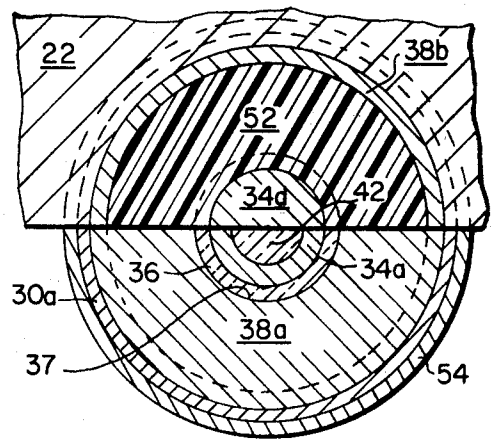


FIG. 3

FIG. 4



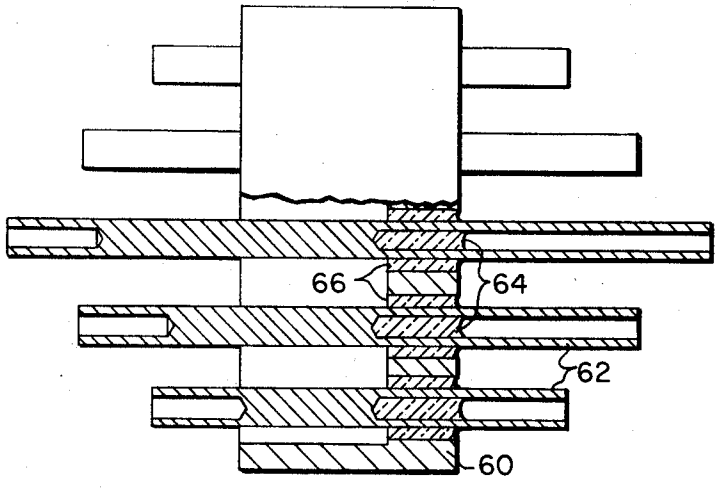


FIG. 5

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HIGH-PRESSURE AND HERMETIC ELECTRICAL FEED-THROUGH APPARATUS

BACKGROUND

This invention relates to electrically insulating seals for feeding electrical conductors through the walls of an enclosure and without leakage even with a large pressure differential across the enclosure wall. Further, the invention provides such seals that remain highly leak-tight, even after exposure to repeated cycling of environmental temperatures and pressures and exposure to radioactivity.

One application of seals which the invention provides is in connection with a nuclear reactor as used for generating electrical power. The reactor is inside a massive enclosure designed to contain radioactive gases even under the conditions of high internal temperature and pressure that theoretically can result from a malfunction of the reactor. Accordingly, the electrical conductors which connect to the reactor must pass through the enclosure within seals essentially as secure as the enclosure walls. These conductors include small gauge conductors for relative small current and voltage transmission, as used for instrumentation purposes, and large gauge power conductors with sizes in the thousands of circular mils.

It is known to feed electrical conductors through pressure enclosures with a ring or annulus of glass sealed about the conductor within the aperture by which the conductor passes through the enclosure. For example, U.S. Pat. Nos. 1,294,466; 1,560,690; 1,564,690; and 2,446,277; and "The art of Sealing Base Metals Through Glass," by W. G. Houskeeper, Transactions A.I.E.E., June, 1923, pp. 870–876, describe such glass-to-metal seal structures. However, the seals which these publications disclose are concerned primarily for use with fine gauge conductors and for feeding them into enclosures such as electron vacuum tubes and lamp bulbs. Also, these prior seals need only withstand, at the most, a pressure differential of one atmosphere. The constructions are considered not sufficiently leak-proof and pressure-tight for use in such critical and adverse environments as are encountered in feeding conductors through a reactor-shielding enclosure.

In addition, U.S. Pat. No. 2,190,302 discloses a glass-to-metal seal in which the conductor being sealed is of highly elastic metal and is tubular with a thin wall, i.e., specified as being in the order of thousandths of an inch or less. A plug of glass fills the tubular conductor along the length where it passes through the outer annular glass seal. Such a construction may be more nearly leak-proof than those described in the other publications noted, but the ultra-thin conductor wall of this patent renders the construction unsuitable for carrying a substantial amount of current.

Accordingly, it is an object of this invention to provide an insulating feed-through seal for an electrical conductor and having improved integrity against leakage.

A more particular object of the invention is to provide such a seal for electrical power conductors, i.e. conductors capable of carrying at least many amperes of current and upwards of several hundred amperes.

A further object of the invention is to provide a conductor-sealing structure of the above character which is not degraded by exposure to radioactivity.

It is also an object of the invention to provide an electrically insulating seal for an electrical conductor and which maintains essentially complete hermeticity under an elevated pressure differential at least as high as 100 psi at elevated temperatures of at least 300° Fahrenheit.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

GENERAL DESCRIPTION

A seal according to the invention employs a conductor element which is constrained from significant deformation inward by means of a tightly fitting core of hard material seated in a hollow within the conductor element. The conductor element passes through an aperture in the wall to which it is sealed, and an electrically insulating member encircles the conductor about the core within this aperture. The wall compressively engages the insulating member which in turn is radially compressed against the conductor element about the core. The wall and insulating member, like the core, are harder than the conductor element. Further, the radial compression of the wall onto the insulating member, and of this member in turn onto the conductor element, is sufficient to deform the core-surrounding walls of the conductor element slightly, and thereby seal the insulating member hermetically to both the wall and the conductor element.

Further, to ensure that large current does not overheat the conductor element, the current-carrying capacity of the element about the core is at the least not significantly less than that of the other portions of the conductor of which the element is a part, i.e. of the conductors extending from either side of the conductor element. This generally requires that the walls of the conductor element about the core be relatively thick so as to have at least as large a cross-sectional area as the rest of the conductor.

Also in accordance with the invention, the aperture-defining wall to which the conductor is sealed is preferably the bulkhead of a header. The header is secured to the rest of the wall at a further larger aperture which the header seals but with the bulkhead of the header outside this further aperture. This configuration spaces the juncture of the header to the rest of the wall longitudinally from the seal between the header bulkhead and the conductor element.

The invention accordingly comprises the features of construction, combinations of elements and arrangement of parts exemplified in the constructions hereinafter set forth, and the scope of the invention is indicated in the claims.

BRIEF DESCRIPTION OF DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a fragmentary side elevation view, partly broken away, of an electrical feed-through fitting for feeding a plurality of electrical power and instrument conductors through a wall with hermetic sealing and embodying features of the invention;

FIG. 2 is an end view of the fitting of FIG. 1 taken along line 2—2 thereof;

FIG. 3 is an enlarged side elevation view, partly in section and partly broken away, of a seal structure em-

bodying the invention and for use in the fitting of FIG. 1;

FIG. 4 is an end view, partly in section, of the seal structure of FIG. 3 taken along line 4—4 thereof; and

FIG. 5 is a fragmentary sectional view taken along line 5—5 of FIG. 2.

DESCRIPTION OF ILLUSTRATED EMBODIMENTS

FIG. 1 shows a penetration **10** which feeds insulated conductors **12** through the wall **14** of a reactor-shielding enclosure **16.** The wall **14** has a biologically shielding concrete core **14***a*, typically several meters thick, with a metal layer **14***b*, typically structural steel many centimeters thick, on each side. A metal nozzle or pipe **18** welded at each end to the layer **14***b* extends through the wall **14** to form a passage for the penetration.

The penetration **10** illustrated is a multiple-conductor feed-through fitting which provides two hermetic seals of each conductor **12** therein to the wall **14,** even under an elevated temperature in the order of 300° Fahrenheit — at which the concrete core **14***a* begins to lose strength — and with a pressure differential across the wall at least in the order of 100 pounds per square inch. Moreover, the radiation which the reactor inside the enclosure **16** might release in the event of an "incident" does not degrade the penetration.

With further reference to FIGS. **1** and **2,** the penetration **10** illustrated has an outer cylindrical steel or other metal tube **20** sealed closed at both ends by metal bulkheads **22** and **24.** The tube extends through the wall **14** concentrically with the pipe **18** and is secured to the wall layers **14***b*, **14***b* by inwardly flanged collar-like fittings **26** and **28,** typically also of metal, that engage the tube portions which protrude beyond the wall **14.** Pressurized gas is maintained within the pipe **18** and end fittings **26, 28**; and also within the bulkhead-sealed tube **20.** As also indicated, an electrical junction box **29** is provided at each end of the penetration for connecting the conductors **12** within it to their respective circuits.

Within the tube **20,** conduits **30,** typically tubes of light-weight metal, enclose each group of one or more conductors **12** along the span thereof between the bulkheads **22** and **24.** Each conduit thus supports a group of one or more conductors and maintains them spaced from other conductor groups, and conducts whatever heat develops from current in the conductors throughout the fitting. In the illustrated penetration, a single conductor **12***a* is within conduit **30***a* and numerous, e.g., 20 or so, instrument and control gauge conductors **12***b* are in the single conduit **30***b*.

As shown in FIGS. **3** and **4,** the seal of conductor **12***a* to bulkhead **22** in accordance with the invention, and which is typical of the seal of this conductor to the other bulkhead **24,** employs a connector pin **34,** which forms the length of the conductor at the seal. The pin **34** is sealed by a glass collar **36** within an aperture **37** through a header **38,** and the header **38** in turn is secured to the bulkhead about a conductor-passing bulkhead aperture **40.** Further, a core **42** of hard material fills an interior hollow **44** within the pin **34** at a median section **34***a* extending along at least the length of the pin within the glass collar **36.** The portions **46** and **48** of conductor **12***a* which extend from either side from the pin **34** are telescopically seated in and compressively crimped or swaged to the pin **34** within sleeves at end sections **34***b* and **34***c* respectively of the pin.

Considering the construction of the seal as shown in FIGS. **3** and **4** in further detail, the connector pin **34** is an elongated rod, preferably with a cylindrical outer surface, of electrically and thermally conductive material which is softer than either the core **42,** the collar **36** or the header **38.** Copper, steel, nickel-iron alloys, tantalum, platinum, silver, and molybdenum are examples of suitable materials, and of these copper is generally used. To form the hollow **44** within the pin median section **34***a* and to form the conductor-receiving sleeve in the end section **34***c*, the pin is centrally bored along its length from the end section **34***c* and through the median section **34***a*. The bore **50** can extend throughout the length of the pin so as to form also the sleeve at the pin end section **34***b*. Alternatively, and as shown, the pin can be bored from each end with an interior bulkhead **34***d* remaining intact between the bottoms of the two bores, i.e., at the end of the pin end section **34***b* adjacent the median section **34***a*. The bulkhead **34***d* is desired to aid in positioning the core, and to prevent internal leakage.

Further in accordance with the invention, the current-carrying capacity of the pin median section **34***a* is not less than, and is preferably equal to or greater than, the current-carrying capacity of the pin sections **34***b* and **34***c* and of the conductor portions **46** and **48** connected to each pin end section. This requirement ensures that the I^2R heating which occurs in the connector pin median section is not significantly greater than, and is preferably less than, elsewhere along the conductor **12.** This requirement thus avoids excessive heating of the pin at the seal thereof to the header **38,** i.e., at the median section. In accordance with these conditions, the cross-sectional area of the bore **50,** along a plane transverse to the length of the illustrated connector pin **34,** i.e., in the plane of FIG. **4,** is the same or less than the area along the same plane of the annular cross-section of the pin at its hollow median section **34***a*. Where the bore **50** and outer surface of the pin median section have circular cross sections, these areas are provided when the ratio of the outer diameter of the pin at the median section to the diameter of the bore at this section is equal to or greater than the square root of two. These dimensions, in turn, require that the walls of the pin median section **34***a* have considerable thickness.

The glass collar **36** extends along the connector pin for a length to provide the necessary strength to support the connector pin and absorb whatever mechanical shocks it is to withstand, and to provide sufficient shear strength in the collar to withstand the maximum pressure specified for the seal. The radial thickness of the seal is determined in accordance with these mechanical considerations and to provide sufficient air space between the pin and header **38** to preclude voltage breakdown between them.

The seal shown in FIGS. **3** and **4** is made, by way of illustrative example, by mounting the pin **34** centered within the header **38** aperture **37** by means of an appropriate jig or fixture. The pin outer surface, at least at the median section **34***a*, preferably is plated with nickel to enhance the bonding of the glass collar **36** to the pin. The glass material for the core **42** is disposed within the hollow **44,** and the glass material for the collar **36** is disposed in the annular space between the pin and header.

These glass materials preferably are sintered preforms having the approximate shapes desired.

The assemblage is then heated, e.g., in an atmosphere-controlled furnace, to a temperature where the glass materials soften sufficiently to fuse. The assemblage is then cooled at a controlled rate to allow the core **42** to harden and for the collar **36** to harden. As the cooling continues, the low thermal contraction of the glass core prevents significant further thermal contraction of the pin at the median section, whereas the header **38** contracts and compressively bears radially inward against the collar **36,** which in turn is radially compressed against the pin. Due to the relative incompressibility of the core **42,** this radial compression of the header **38** compresses the collar **36** between the header and pin with such force that the material of the pin is stressed beyond its elastic limit and hence yields and flows. The final result is a solid, intimate and compressively stressed seal of the glass collar **36** between the header and pin. As also indicated in FIG. **3,** an electrically insulating potting compound **52** is preferably applied over the header **38**-pin **34** juncture to preclude contamination of the seal by foreign matter and to otherwise avoid contamination of the seal in an adverse environment.

As indicated above, the resultant seal is truly hermetic in that the leakage through it is far less than 1×10^{-6} standard cc. per second i.e., cc. per second per atmosphere at room temperature). In fact, the leakage through such a seal made in accordance with the invention is at least two orders of magnitude less than this value. Also, the seal is permanent; it remains uniformly and consistently tight during exposure to widely fluctuating environmental temperatures, exposure to relatively high levels of radioactivity, elevated temperatures in excess of 300° Fahrenheit and pressures in excess of 100 pounds per square inch. Moreover, due to the dimensional relationship between the electrically conductive material in the connector pin at the median section relative to the area of the bore therein, and more generally relative to the rest of conductor **12***a*, the pin remains sealed in this manner to the header **38** during the passage of the maximum current of the conductor **12***a* through the connector pin.

The core **42** and collar **36** are referred to as being of glass for clarity of description. The glass, which is considered a preferred material, can be either so-called hard glass or soft glass, and other material also can be used. Specifically, the core **42** need not be electrically insulating. Further, it can be press-fitted into the bore and then can be of a material, such as molybdenum, which does not melt below the melting temperature of the pin **34** or header **38.** However, the core should be of a material harder than the pin **34** and with a lower coefficient of thermal expansion.

As used herein, the term "hard" means that a material, such as that of the core resists deformation whether elastic or non-elastic more than another material, such as that of the pin **34.** The term "softer" has the opposite meaning, i.e., as used herein, the pin **34** is of softer material than the core **42.**

With regard to the collar **36,** it should be of electrically insulating material. Also, the material for the collar **36,** and for the core **42** where it is fused into place, should soften to the point of fusing at temperatures well below the temperatures at which the pin **34** and header **38** become soft. Conversely, on cooling the two materials should solidify at a sufficiently high temperature so that the header **38** thermally contracts upon further cooling from this temperature. Also, it will be understood that the collar **36** and core **42** must be considerably harder than the pin **34** and at least equally as hard as the header **38.**

The header **38,** which in the illustrated construction is a separate element from the bulkhead **22** for ease in fabricating the seal to the conductor **12***a* in the manner described above and which hence is part of a pressure barrier or bulkhead, is of a material harder than the pin **34** and also with a coefficient of thermal expansion large enough to provide, upon cooling from the temperature at which the core **42** and collar **36** fuse, sufficient thermal contraction to compressively clamp the collar between it and the pin, as described above. A further desirable characteristic of the header **38** is that it be non-magnetic and have a sufficiently low electrical conductivity to minimize eddy current and electrical hysteresis losses in it. By way of illustrative example, the header **38** can be of stainless steel.

With further reference to FIG. **3,** and as shown in FIG. **1,** the header **38** is secured to the bulkhead **22** so that the seal to the pin **34** is offset from the juncture of the header to the bulkhead. This arrangement removes the seal from mechanical and thermal disturbances at the bulkhead. It also facilitates securing the header to the bulkhead without disturbing the seal, e.g., the heat and stresses of welding the header to the bulkhead are sufficiently isolated from the seal to prevent disturbing it. For this purpose, the illustrated header **38** is shaped roughly like a shallow cup with a central bottom bulkhead **38***a* to which the pin **34** is sealed by way of the collar **36,** and with an outer peripheral collar **38***b* extending from it longitudinal to the pin **34.** This collar **38***b* telescopically fits within the aperture **40** and is readily welded to the bulkhead **22** to form a secure and hermetic seal between the plug and the bulkhead. With this construction, the thickness of the header **38***a* is outside of the bulkhead aperture **40.** It will be seen in FIG. **3** that the potting compound **52** can fill the interior of the cup-shaped header about the pin **34.**

Another reason for using a header **38** separate from the bulkhead **22** is that it allows each part to be of different material to optimize performance at relatively low cost.

FIG. **3** also shows the structure that mounts the conduit **30***a*, within which the conductor **12***a* extends in the penetration **10,** to the bulkheads **22** and **24.** The mounting leaves the conduit free for longitudinal motion relative to the bulkhead to accommodate thermal and other dimensional changes. In particular, the end of the conduit adjacent bulkhead **22** is slidably seated within a ring **54** secured, as by welding, to the inner surface of the bulkhead. The ring is concentric to the pin **34.** Further, in the illustrated seal, the pin **34,** and the apertures **37** and **40,** and the ring **54** are all circular along the plane of FIG. **4** and are mutually concentric. Alternative to using the ring **54,** three pins (not shown) can be secured to the bulkhead **22** in its place, the pins being equally spaced on a circle.

Turning to FIG. **5,** the seal between each of the multiple conductors **12***b* and the bulkhead **22** is made with a plug **60** having a number of connector pins **62, 62** sealed to it, each in a manner similar to the seal of FIGS. **3** and **4.** The pins **62** are of graded different lengths according to the radial distance of each from

the center of the header, with those at the center of the header being longest. This facilitates ready mechanical access to each pin, as is desirable for crimping or otherwise connecting a conductor **12***b* to it. In particular, each pin **62** has a bore extending along part of the length thereof from one end into the median section where it is sealed to the plug **60.** A core **64** fills the bore at the pin median section to restrict compressive collapse of the pin. An insulating collar **66,** of vitreous or like material as described above with reference to the collar **36** of FIG. **3,** is compressively clamped between the header and the pin to form the seal. As also described above, the bore in each pin **62,** at least in those likely to carry significant current, has a cross-sectional area not significantly greater than the cross-sectional area of the pin wall around it in the pin median section.

In sum, the invention provides an electrical feedthrough construction which seals each electrical conductor to the bulkhead or other wall being penetrated with permanent hermeticity that withstands such adverse conditions as high temperature, high pressure, mechanical shock and radiation, as well as being capable of large current, typically hundreds of amperes at potentials of several thousand volts or more. In each seal, a connector pin has an inner hollow filled with a core of material harder and of a lower coefficient of thermal expansion than the pin. A rigid collar of insulating material encircles the core-filled hollow section of the connector pin and is in turn encircled by a disk or plate-like member which compresses the collar radially inward onto the pin. The core restrains the pin from deforming radially inward, both due to mechanical pressure and thermal contraction, away from the collar.

Further, the current-carrying capacity of each connector pin at the core-filled hollow section is at least commensurate with that of the rest of the conductor to which the pin is connected. As described, where the hollow-forming bore also forms a conductor-seating sleeve at the end of the pin, this generally results in the core having a cross-sectional area not materially less than, and preferably at least equal to, the cross-sectional area of the pin walls encircling the core.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described the invention, what is claimed as new and secured by Letters Patent is:

1. Apparatus for securing an electrical conductor with an essentially leak-proof pressure-tight seal to a wall member through which the conductor passes, said apparatus comprising

A. a substantially homogeneous and solid core of a first material fusible at a first temperature,

B. a tubular electrical conductor of a second material containing said core therein and being radially compressed thereagainst,

C. a collar-like member of electrically insulating material fusible at said first temperature, said collar-like member encircling said conductor about said core and being radially compressed thereonto,

D. a pressure-barrier having an aperture therethrough, and having said conductor passing through said barrier at said aperture with said collar-like member disposed in said aperture, and radially compressed onto said collar-like member,

E. each of said collar-like member, said barrier, and said core being of material harder than the material of said conductor, and each of said conductor and said pressure-barrier being solid at said first temperature and melting only at a temperature in excess thereof.

2. Apparatus as defined in claim **1** in which the cross-sectional area of said conductor around said core is not substantially less than the cross-sectional area of said core.

3. Apparatus as defined in claim **1** in which said pressure barrier is of metal and said core and collar-like member are of vitreous material.

4. Apparatus as defined in claim **1** in which

A. said pressure barrier is heat-shrunk onto said collar-like member to exert said radial compression onto it,

B. said core is of material having a lower coefficient of thermal expansion than said conductor, and

C. said tubular conductor is heat-shrunk onto said core.

5. Apparatus as defined in claim **1** in which said pressure barrier radially compresses said collar-like member onto said conductor with sufficient force to deform said conductor permanently.

6. Apparatus as defined in claim **1** further comprising an electrically conducting tubular member of said second material joined to an end of said tubular conductor and applying an electrical conductor telescopically seated therein in series with said tubular conductor, said tubular member having a conductor-receiving bore therein with a cross-sectional area not substantially greater than the cross-sectional area of said conductor around said core.

7. Apparatus as defined in claim **1** further characterized in that said barrier is of a material harder than said conductor and softer than either said core or said collar-like member.

8. Apparatus as defined in claim **1** in which said barrier is of material harder than said first member, softer than said core and than said collar-like member, and having a greater coefficient of thermal expansion than said core and than said collar-like member.

9. Apparatus as defined in claim **1** in which said second material of said conductor has a greater coefficient of thermal expansion than said first material of said core.

10. Apparatus as defined in claim **1** in which said conductor is of copper and said barrier is of stainless steel and said collar-like member is of glass.

11. Apparatus for securing an electrical conductor with an essentially leak-proof pressure-tight seal to a wall member through which the conductor passes, said apparatus comprising

A. means forming a pressure barrier having a conductor-passing aperture therethrough,

B. an elongated first member of electrically conductive material, said member

1. having a hollow median section between first and second further sections and delivering current received at one further section to the other further section by way of said median section,
2. having at said hollow median section a first cross-sectional area of said conductive material not substantially less than the minimum cross-sectional area of said conductive material elsewhere therealong,
3. passing through said aperture with said median section extending within said aperture for at least a first length and spaced inwardly therefrom,

C. a solid and substantially homogeneous body filling said hollow median section and radially compressed thereagainst substantially along said first length thereof, said body being of a material which melts at a temperature below the melting temperatures of, and which when solid is harder than, the materials of said barrier means and of said first member, and

D. an annular collar-like seal encircling said median section along said first length thereof and sealing the space therealong between said median section and the aperture-defining walls of said barrier means, said seal being of an electrically insulating material which melts at a temperature below the melting temperatures of, and which when solid is harder than, the materials of said barrier means and of said first member.

12. Apparatus as defined in claim **11** further characterized in that

A. said first member has a coefficient of thermal expansion greater than that of said second material, and

B. said barrier means is of a material having a coefficient of thermal expansion greater than that of said second material and of said seal.

13. Electrical feed-through apparatus comprising

A. wall means forming a pressure bulkhead having a conductor-passing aperture therethrough,

B. an electrical conductor-connecting pin disposed in and extending through said aperture, said pin
1. having a hollow median section between first and second further sections and delivering current received at either further section to the other further section by way of said median section,
2. having a free end on at least one said further section and having first sleeve means at said free end for telescopically seating an electrical conductor therein,
3. disposed with said median section extending within said aperture for at least a first length and spaced inwardly therefrom,
4. having the wall of said hollow median section forming an annular area, along a first plane transverse to the length of said median section, not substantially less than the area along a plane parallel thereto which said sleeve means encircles,

C. a solid and substantially homogeneous core of fused-in-place material filling said hollow median section at least substantially along said first length thereof, and

D. an annular collar-like seal of vitreous material fused in place encircling said median section along said first length thereof and sealing the space therealong between said median section and the aperture-defining walls of said bulkhead,

E. each of said core and said seal being of material which melts at a temperature below the melting temperature of the materials of said bulkhead and of said pin.

14. Apparatus as defined in claim **13** in which

A. said pin is of material softer than the materials of said bulkhead, said core, and said seal,

B. said bulkhead is of material having a coefficient of thermal expansion larger than that of the materials of said core and of said seal, and

C. said pin is of material having a coefficient of thermal expansion larger than that of the material of said core.

15. Apparatus as defined in claim **13** in which said wall means comprises

A. a plate member of first thickness and with a first aperture therethrough,

B. a panel member
1. having said conductor-passing aperture therethrough and sealed closed with said pin and said collar-like seal,
2. secured to said plate member with said pin passing through said first aperture, sealing said first aperture closed, and with the thickness thereof at least partly removed from the thickness of said plate member along the direction in which said apertures pass.

16. Apparatus for securing an electrical conductor with an essentially leak-proof pressure-tight seal to a wall member through which the conductor passes, said apparatus comprising

A. a core of a first material,

B. a tubular electrical conductor of a second material containing said core therein and being radially compressed thereagainst,

C. a collar-like member of electrically insulating material encircling said conductor about said core and being radially compressed thereagainst,

D. a pressure barrier having an aperture therethrough, and having said conductor passing through said barrier at said aperture with said collar-like member disposed in said aperture, and radially compressed onto said collar-like member, said pressure barrier comprising
1. a panel portion of a first thickness and having said aperture therethrough, and
2. a tubular portion radially outward from said aperture and extending from said panel portion along the same direction as the passage of said aperture for a distance at least equal to said first thickness,

E. each of said collar-like member, said barrier, and said core being of material harder than the material of said conductor.

17. Apparatus as defined in claim **16** further characterized in that said wall member includes a further panel portion parallel to said panel portion of said barrier and with an opening therethrough, said further panel portion mounting said barrier at said opening by means of said tubular portion.

18. A method of securing an electrical conductor with an essentially leak-proof pressure-tight seal to a wall member through which the conductor passes, said method comprising the steps of

A. providing a pressure barrier with a conductor-passing aperture therethrough,

B. disposing said conductor passing through said pressure barrier centered within said aperture and radially spaced inwardly therefrom,

C. providing a central hollow in said conductor at least along the length thereof within said pressure barrier and with a cross-sectional area substantially equal to the cross-sectional area of said conductor outward of said hollow,

D. filling said radial space between said conductor and said pressure barrier with vitreous material and filling said length of said hollow with vitreous material,

E. providing said vitreous materials to have lower melting temperatures and lesser coefficients of thermal expansion, than the materials of said conductor and of said pressure barrier,

F. heating said assembled pressure-barrier, conductor, and vitreous materials to fuse said vitreous materials in place, and

G. cooling said assembled elements.

19. The method defined in claim **18** comprising the further steps of providing said wall member with an aperture therethrough, and affixing said pressure barrier with said conductor secured therein to said wall member to close said aperture therethrough.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,735,024 Dated May 22, 1973

Inventor(s) Edward R. Walker, Sr.

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

Column 1, line 23, "relative" should be --relatively--.

Column 1, line 32, "art" should be --Art--.

Column 2, line 63, after "wall" insert --member--.

Column 3, line 34, change "with" to --within--.

Column 5, line 28, before "i.e." insert -- (--.

Column 6, line 39, after "header" insert --bulkhead--.

Signed and sealed this 6th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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