

April 21, 1959

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2,883,638

PNEUMATIC ELECTRICAL CONNECTOR

Filed Aug. 22, 1957

2 Sheets-Sheet 1

Fig. 1.

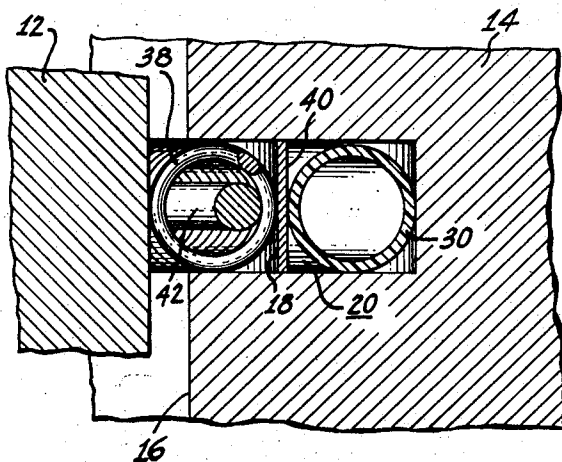
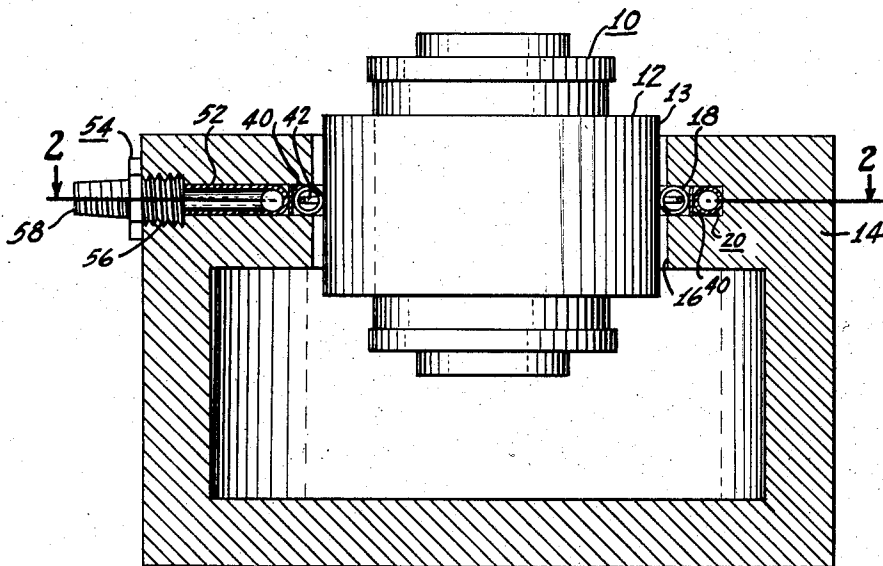


Fig. 3a.

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Fig. 2.

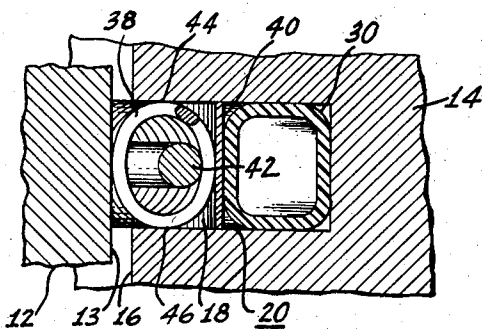
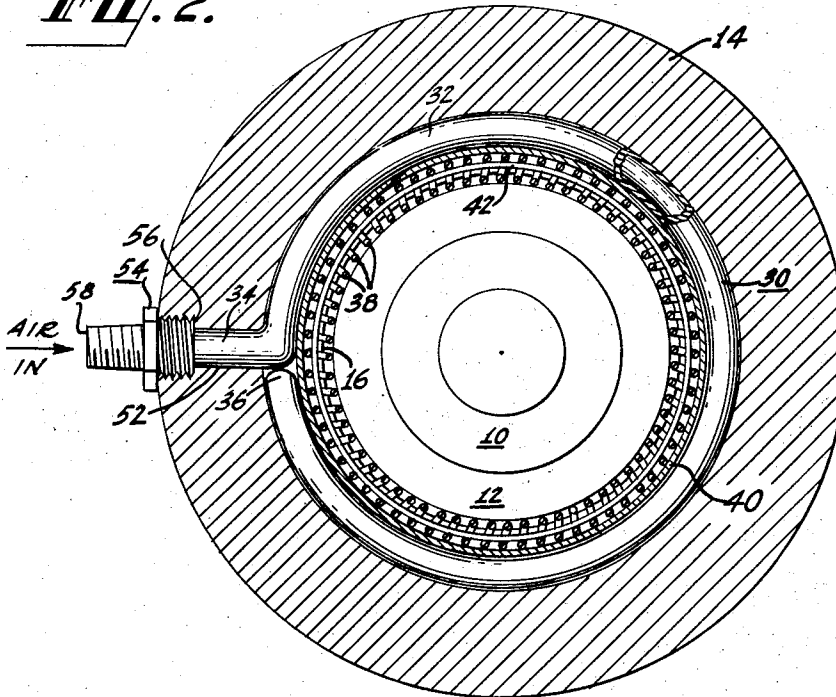


Fig. 3b.

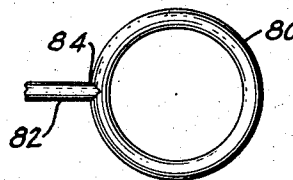


Fig. 4.

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2,883,638

PNEUMATIC ELECTRICAL CONNECTOR

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Application August 22, 1957, Serial No. 679,719

6 Claims. (Cl. 339—117)

This invention relates to electrical connectors of the type used to make contact between two spaced apart surfaces. Although suitable for connecting together two spaced planar surfaces, this invention finds particular applicability in electrically connecting an external cylindrical surface with a closely spaced, surrounding coaxial and coextensive, internal cylindrical surface. The problem of connecting together such opposed cylindrical surfaces is commonly encountered in electronic equipment using high frequency, super power electron tubes; and for this reason the present invention will be described as applied to such equipment. However, it should be appreciated that neither the shape of the members to be connected nor the application thereof is a limitation upon the scope of applicability of my invention.

According to present-day design, internal electrodes of high frequency super power tubes are frequently provided with external terminals in the form of annular members sealed through the tube envelope wall and forming a portion thereof. These annular terminals are often connected either directly to associated resonant cavities or else to external circuitry wherein the tube is seated in a cylindrical socket. In either case electrical contact must be made between the external cylindrical surface of the tube's annular terminal and an opposed, spaced, mating, internal cylindrical surface of the cavity or socket.

In providing mutual contact between two such mating surfaces as described above, consideration must be given to the extremely high currents that will be conducted therebetween, the extremely high radio frequencies involved, and the force that must be overcome in order to insert the tube into its socket or to remove it therefrom. The consideration of high currents demands that a high conductivity contact exist. This usually means, among other things, that there be relatively high contact pressure. The consideration of high frequencies calls for large surface area contact since skin effect, or surface conduction, exists at high radio frequencies. Insofar as the third consideration of insertion or removal force is concerned, there should be substantially less sliding friction between the mating surfaces and the connector during insertion or removal of the tube than exists during maintained engagement.

According to the prior art, flexible conductive means, e.g., a circular array of spring fingers or a toroidal coil spring, is used to connect such a tube into its socket. In the former case, the spring fingers may be attached to the tube socket around the periphery of the socket's internal cylindrical surface. With a tube in operating position in such a socket, these fingers bear against the spaced, coaxial, external, cylindrical terminal surface of the tube. In the latter case, the toroidal coil may be received in a shallow circumferential groove around the internal cylindrical surface of the socket. A portion of each turn of the coil bears against the spaced, external cylindrical surface of the tube terminal.

In either of these prior art methods, spring force alone is used to maintain contact pressure between the connec-

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tor apparatus and the mating surfaces. At high currents, the I^2R losses at the points of contact are sufficient to overheat the spring material causing a relaxation that results in reduced contact pressure thus increasing the contact resistance. When the contact resistance is increased, the I^2R heating losses are even more pronounced. The continuous cycling of this heating and relaxing is usually sufficient—if currents are high—to burn away or completely melt the spring contact metal. Furthermore, in these prior art methods where contact pressure is made by spring force alone, the spring force must be overcome in order to insert the tube into its socket. This is inconvenient if not difficult or even near impossible in the case of large tubes. In some cases the force necessary to insert a tube into its socket is so great that mechanical or hydraulic equipment must be used. In such cases, dangerously high strains are exerted on the vacuum seals of the tube envelope. Ideally then, the connector apparatus should be such that only a small force—if any—need be applied in order to insert the tube into the socket; but once the tube is in place, the connector apparatus should be capable of exerting a relatively much greater force during maintained engagement.

It is, therefore, a principal object of my invention to provide such an ideal electrical connector. Some of the other objects of my invention are: to provide an electrical connector capable of making a high conductivity connection between two spaced opposed parallel surfaces; to provide a novel electrical connector having a relatively large surface contact area; to provide an electrical connector which permits easy engagement and disengagement of the parts to be connected together; to provide an electrical connector which affords an unusually high contact pressure during maintained engagement; and to provide an electrical connection whose contact pressure or conductivity will not be lessened when subjected to heat.

According to my invention these objects are realized through the provision of a flexible conductive means, preferably a toroidal, coil spring contact member which is pressed into contact with the members that are to be connected by hydraulic or pneumatic means.

In connecting a high frequency, super power electron tube into its socket, as hereinbefore mentioned by way of example, a channel is provided circumferentially around the internal cylindrical surface of the socket. An inflatable tubular bladder is longitudinally disposed in the channel in contact with the base of the channel and extends completely around the socket. A tightly wound toroidal coil spring is disposed adjacent the bladder in the channel longitudinally axially parallel to the bladder and is spaced from the base of the channel by the bladder. To make an electrical contact between the opposed cylindrically surfaced members of the electron tube and its socket, the bladder is inflated by applying a fluid pressure thereto. Expansion of the bladder causes the toroidal coil spring to be laterally deformed and urged out of the channel against the external cylindrical surface of the electron tube and at the same time against the side walls of channel. Thus, a high pressure contact is made by the conductive toroidal coil spring against both the electron tube and its socket.

Contrary to prior art apparatuses, the connector of my invention is not subject to the unreliability of contact pressure made by spring force alone. According to my invention the contacting spring can be readily cooled because the thermal path through the spring metal can be very short. And moreover, being tightly wound, the compressed, deformed, spring approaches the thermal conductivity of a solid metallic conductor. If, for any reason, cooling of the contacting coil spring should be insufficient and it should relax due to overheating, either by its own I^2R losses or by an outside heat source such as the elec-

tron tube terminal, contact force will be sustained and contact resistance will remain low. In the event of coil spring relaxation from any cause, pressure in the inflatable elastic bladder applying lateral force to the spring will follow through and maintain contact pressure and contact conductivity.

In answer to another objection to prior art apparatuses, my invention permits easy insertion of the tube into its socket. During insertion and removal of the tube, the fluid pressure may be released from the bladder allowing the coil spring to recede into the channel, thus removing frictional contact between the tube and its socket.

Referring to the drawings:

Figure 1 is an elevation view in partial cross-section of a high frequency, super power electron tube electrically connected to a mating resonant cavity apparatus by connector apparatus according to my invention.

Figure 2 is a plan view in partial cross-section of the apparatus of Figure 1 taken along line 2—2 of Figure 1. Figures 3 and 3a are enlarged detail views in cross-section of the connector according to my invention.

Figure 4 is a plan view of an alternative embodiment of an inflatable bladder according to my invention.

Referring to Figures 1 and 2, a high frequency super power electron tube 10 having an electrode terminal 12 with an external cylindrical surface 13 is contained in a resonant cavity apparatus 14 which has an opposed, spaced, mating internal cylindrical surface 16. The cavity apparatus 14 is provided with a circumferential channel 18 around and in its internal cylindrical surface 16. Within this channel is disposed an electrical connector apparatus 20 whose detailed description is more clearly set forth with reference to Figures 3a and 3b.

Referring to Figure 3a, the connector apparatus 20 includes an inflatable tubular bladder 30 which is located in the bottom of the channel 18. As shown in Figure 2 the bladder 30 comprises a single length of inflatable tubing which is looped on one end to provide a ring portion 32 and an extension portion 34. An end 36 of the tubing contained in the ring portion 32 is sealed so that the length of tubing may present an air tight inflatable bladder when a fluid pressure source is connected to the free end of the extension portion 34. The bladder extends around the circumferential channel 18 and has a cross-sectional diameter approximately equal to the channel's width. A toroidal coil spring 38, which is situated adjacent the bladder in the channel near its mouth at the cylindrical surface 16 of cavity apparatus 14, also extends around the channel, and also has a cross-sectional diameter approximately equal to the width of the channel. The bladder 30 and the toroidal spring 38 are separated by an annular metal shim 40 which comprises a length of ribbon-like metal stock formed into a circle. As shown in Figure 2, the shim has its two ends slightly overlapped so that it is free to contract in diameter against the spring when the bladder is inflated. The shim serves both to protect the bladder 30 from being pinched by the spring and to transmit the force of the bladder, when inflated, to a central point on the spring. In order to prevent the toroidal spring 38 from becoming disengaged from the channel 18, a snap ring 42 is disposed within and throughout the length of the spring and has a slightly larger diameter than does the spring, thus maintaining the spring in an overall circular configuration and causing it to be retained in the channel. The snap ring may comprise a length of spring wire circularly formed with overlapping ends similar to the shim.

The depth of the channel 18 is approximately equal to, or slightly less than, the sum of the cross-sectional diameter of the deflated bladder, the coil diameter of the toroidal spring, and the cross-sectional thickness of the annular shim. With such relative dimensioning and with the bladder deflated, the toroidal spring is disposed partly protruding from the channel 18 such that its sides do remain

within the side walls of the channel and at the same time projects to within the proximity of the electrode terminal 12 of the electron tube 10.

In Figure 3b the connector apparatus 20 is shown with the electron tube 10 in engaged position and with the bladder 30 inflated. In contrasting Figure 3b with Figure 3a, it can be seen that in operation the bladder 30 expands taking up more room in the channel and moving the shim 40 against the toroidal coil spring 38 and toward the electron tube terminal 12. The spring 38 is compressedly deformed and urged both against the side walls of the channel at points 44 and 46 and against the cylindrical surface 13 of the terminal 12. As a result large surface, high pressure, contact is made at these three points thus providing a highly conductive connection between the tube electrode terminal 12 and the cavity member 14.

Referring again to Figures 1 and 2, bladder inflation access means is provided through the wall of the cavity apparatus 14. The access means may simply comprise a bore 52 connecting the base of the channel 18 to a double ended high pressure hose fitting 54 fastened to an external portion of the cavity apparatus 14. As such, the fitting 54 is adapted to receive the extension 34 of the bladder onto one of its ends 56 and to be connected to a source of fluid pressure (not shown) at its other end 58. Connection of the bladder extension 34 to the source of fluid pressure may be made in any manner conventional to high pressure hose connection. The apparatus shown in Figures 1 and 2 is a schematic illustration only, and is not meant to form any part of my invention or limit the scope thereof. It should, however, be appreciated that due to the high pressure involved, any hose fitting used must be one of a type especially designed for high pressure connection.

Figure 4 illustrates an alternative form of inflatable bladder in which a continuous ring 80 of inflatable tubing is provided with an integral extension portion 82 extending from the ring 80 at a T intersection 84. In using such a bladder, the ring portion 80 is situated in the channel 18 while the extension 82 connects through the bore 52 to the fluid pressure source.

In one embodiment of my invention as applied to a resonant cavity and electron tube installation as illustrated in Figures 1 and 2, the toroidal coil spring 38 was constructed of tightly wound .015 inch diameter silver-plated beryllium-copper wire to a coil diameter of 0.125 inch and an annular diameter of 5.670 inches. The channel 18 was machined to a depth of 0.200 inch and a width of 0.127 inch. The shim 40 was made of 0.020 inch thick stainless steel with an annular diameter of 5.820 inches. The bladder 30 was made of 0.125 inch diameter plastic tubing according to the illustration of Figure 3. The snap ring 42 was made of .050 inch steel piano wire and had an annular diameter of 5.300 inches. The internal cylindrical surface 16 of the cavity 14 had a diameter of 6.072 inches and the electron tube was a 100,000 watt ultra high frequency triode whose external cylindrically-surfaced terminal 12 had a diameter of 5.600 inches. An air pressure of 300 p.s.i. was applied for bladder inflation. In operation, currents in the nature of 60 amperes at 1000 mc. were passed through the connector apparatus 20.

Considering that the figure of merit, or quality measurement Q, of an electrical circuit is represented as

$$Q = \frac{X_L}{R}$$

where X_L is inductive reactance and R is pure resistance, and further that in many applications a high Q is desirable, the following theoretical and measured values were noted for the installation set forth above. The calculated theoretical Q of the cavity was 500; the measured Q using a connector composed of spring fingers according to the prior art was approximately 400;

and the measured Q using the embodiment of my invention as described above was increased to approximately 443. As can be readily appreciated by those skilled in the art, this increased Q resulting from decreased contact resistance, presents a highly desirable feature in addition to the other advantages hereinbefore described.

What is claimed is:

1. An electrical connector comprising a conductive member having a channel therein, a tubular inflatable bladder longitudinally disposed in the bottom of said channel, a coil spring longitudinally disposed in said channel on top of said bladder and longitudinally axially parallel therewith, and bladder inflation access means connected to said bladder.

2. Electrical connector apparatus for connecting a first metal member having a channel therein to a second metal member comprising a tubular inflatable bladder longitudinally disposed in said channel, the deflated diameter of said bladder being substantially equal to the width of said channel, a coil spring disposed in said channel longitudinally axially parallel to said bladder, said spring having a diameter substantially equal to the width of said channel, an elongated ribbon shim member interposed between said bladder and said spring so that said bladder contacts one side of said shim and said spring contacts the other side of said shim, said spring being in proximity to said second metal member, bladder inflation access and means connecting to said bladder adapted to receive a source of fluid pressure for inflating said bladder.

3. Electrical connector apparatus for connecting a first metal member having a rectangular channel therein to a second metal member comprising a tubular inflatable bladder longitudinally disposed in said channel, the deflated diameter of said bladder being substantially equal to the width of said channel, a coil spring disposed in said channel longitudinally axially parallel to said bladder, said spring having a diameter substantially equal to the width of said channel, an elongated ribbon shim member interposed between said bladder and said spring so that said bladder contacts one side of said shim and said spring contacts the other side of said shim, said spring being in proximity to said second metal member, and bladder inflation access means connected to said bladder.

4. An electrical connector for connecting a first terminal member having an external cylindrical surface with a second terminal member having an internal cylindrical surface spaced from said external cylindrical surface, said second terminal member having a channel therein opening toward said external cylindrical surface of said first terminal member, said channel being approximately twice as deep as it is wide, said connector comprising an inflatable tubular bladder disposed in the bottom of said channel axially parallel therewith, said bladder having a diameter substantially

equal to the width of said channel; a flat ribbon-like shim having a width substantially equal to the width of said channel transversely disposed in said channel and axially parallel thereto with one of its sides in abutment with said bladder; a coil spring disposed in said channel longitudinally axially parallel therewith and in abutment with the other side of said shim, said spring having a diameter substantially equal to the width of said channel; and bladder inflation access means communicating through said second terminal member and connected to said bladder; whereby said bladder may be inflated causing said shim to move against said spring causing said spring to be laterally deformed and urged against the side walls of said channel and out of said channel against said surface of said first terminal member to make large area high pressure contact with both said side walls and said surface of said first terminal member.

5. Apparatus for receiving an electron tube, said tube having an electrode terminal with an external cylindrical surface, comprising: a conductive member having an internal cylindrical surface radially spaced from and co-axial with said tube terminal surface, said conductive member having a circumferential rectangular channel therein whose depth is substantially equal to twice its width, an inflatable tubular bladder disposed circumferentially in said channel, a toroidal coil spring adjacent said bladder in said channel and extending laterally to within the proximity of said external cylindrical terminal surface, and inflation access means communicating through said member to said bladder, whereby said bladder may be subjected to fluid pressure through said access means to inflate said bladder and laterally deform said coil spring and urge it both against the side walls of said channel and out of said channel into contact with said external cylindrical terminal surface to make an electrical connection between said member and said terminal.

6. Electrical connector apparatus comprising a metal member having a rectangular channel therein, a tubular inflatable bladder, an elongated flat ribbon shim, and a coil spring all disposed longitudinally axially parallel to and within said channel in stacked contiguous array from the base of said channel outward thereof in the order named, said shim having a width and said bladder and said spring having diameters substantially equal to the width of said channel, the depth of said channel being substantially equal to the sum of the diameter of said bladder, the diameter of said spring and the thickness of said shim, and bladder inflation access means communicating through said metal member to said bladder.

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