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ELECTRICAL CONNECTOR

Frank C. Rushing, Ellicott City, Md., assignor to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

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ABSTRACT OF THE DISCLOSURE

An electrical connector for use in vacuum, explosive environments incorporating mating abut type contacts in a lever driven cam operated connector assembly. The movable contact assembly is moved through an arcuate path during connector engagement and disengagement thereby establishing a shear force between the contact surfaces of the connector. This motion produces contact wiping action which provides good electrical contact and exerts sufficient force to disengage the contacts under high friction or weld conditions experienced under vacuum conditions. A spring loaded shield is provided to isolate the connector contacts from the external atmosphere during contact engagement and disengagement to eliminate the hazards of explosion.

This invention relates to electrical connectors, and more particularly, to electrical connectors adapted for use under high vacuum conditions such as found in space.

There are many difficult problems encountered in the design of electrical connectors to be used in the high vacuum conditions of outer space. A good electrical connection requires intimate contact between two terminals, preferably made of soft metals which are wiped together under pressure. Unfortunately, as the degree of vacuum is increased, the friction coefficient between the contacts and the chance of welding the contacts increase. Although considerable progress has been made in the development of materials that will maintain low friction coefficients and will withstand welding, the operation of terminals made of these materials under a variety of conditions in a high vacuum is still questionable.

More specifically, the use of a typical female-male connector of the prior art has been unsatisfactory under high vacuum conditions. Typically, such connectors present large surfaces which are brought into intimate contact with each other under pressure to thereby provide a better electrical connection and also to remove insulating contaminants. However, the use of such contacts in a high vacuum environment is accompanied by higher wiping forces due to the higher coefficient of friction between the surfaces of the male-female contacts and the terminals may even weld together. In order to separate contacts of this type, it would be necessary to exert a large force upon the respective terminals thereby possibly galling the contacts or damaging their supports.

The connector of this invention has been designed so that the terminals may be connected and disconnected with a manual action of minimum complexity and minimum effort. Typically, the person using this connector will be an astronaut dressed in a space suit. The manual dexterity of an astronaut is limited by the pressurized space suit and by the unfamiliar gravitational field. As a result, the connector of this invention must be designed to avoid tediousness in mating the two parts of the connector and to avoid difficulty of forcing the two parts together or apart.

It is, therefore, an object of this invention to provide a new and improved electrical connector adapted to be used in a high vacuum condition with a simple manual act and minimum effort.

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It is a further object of this invention to provide a new and improved electrical connector whereby the problems encountered in a high vacuum condition of increased friction coefficients and of welding the surfaces of the terminals are overcome.

It is a more particular object of this invention to provide a new and improved electrical connector having a high density of terminals and capable of providing a high shearing force to disengage any high friction or welded terminals.

It is a still further object of this invention to provide a new and improved electrical connector which is sealed against dust and humidity, and which will prevent any possible arcing between the terminals from igniting the surrounding atmosphere.

These and other objects are accomplished in accordance with the teachings of the present invention by providing a new and improved electrical connector including first and second assemblies for supporting in high density arrays first and second sets of contacts to be mated with each other. The contacts of one of said sets are spring biased in a direction substantially perpendicular to the mating surface of the contacts of the other set. A lever is pivotally mounted upon one of the assemblies for engaging and disengaging the sets of contacts to and from each other. More specifically, the lever has a first cam surface for exerting an engaging pressure on the other assembly, and a second cam surface for exerting a disengaging force upon the other assembly and for establishing a shearing force upon the sets of contacts. The lever is pivotally mounted upon one of the assemblies so that the point of pivoting is approximately in the plane in which the contacts of both assemblies engage each other. As a result, a high mechanical advantage will be achieved and a high shearing force will be exerted upon the contacts to thereby disengage any welded contacts with relatively little force exerted upon the lever.

These and other objects and advantages of the present invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIGS. 1 and 2 show side views of an electrical connector in accordance with the teachings of this invention in which there is particularly illustrated the details of the lever and detent mechanisms of an embodiment of this invention;

FIG. 3 is a sectional view of the electrical connector shown in FIGS. 1 and 2;

FIG. 4 is an enlarged, detailed view of the mating electrical contacts as incorporated in the electrical connector of FIGS. 1, 2 and 3; and

FIGS. 5a and 5b show diagrammatically how a shearing force is developed upon the contacts of the electrical connector of this invention.

Referring now to the drawings and in particular to FIGS. 1 and 2, there is shown an electrical connector 10 including an upper assembly 12 and a lower assembly 14 for supporting in high density arrays two sets of engaging contacts. Cables 16 and 20 are respectively inserted through appropriate sealing members 18 and 22 such as grommets made of a silicone rubber into the assemblies 12 and 14. The sets of the contacts associated with the assemblies 12 and 14 are engaged and disengaged by a set of levers 24 which are pivotally mounted upon pins 32 associated with the lower assembly 14. More specifically, the pins 32 are secured in a suitable manner to support members 36 which in turn are secured upon the periphery of the assembly 14. Further, the levers 24 include handles 26 which extend away from the pins 32, and cam surfaces 28 which engage a set of second pins 34 for exerting an engaging force upon the assembly 12 moving it downward and slightly to the right. The pins

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34 are secured to support members 38 which are in turn disposed upon the outer surface of the upper assembly 12. Further, the levers 24 have cam surfaces 30 which when the levers 24 are rotated in a counterclockwise motion (as seen in FIG. 1) exert a force upon the pin 34 and the upper assembly 12 moving it upward and slightly to the left. The slight movements to the right and to the left provide a wiping action between the electrical contacts which is desirable both for closing (to make a good connection) and for opening (to shear welded contacts apart).

A detent 42 is provided to latch the levers 24 and to insure that the assemblies 12 and 14 are held together when the electrical connector is engaged. More specifically, the detent 42 is pivotally supported upon the lower assembly 14 by a pair of projections 40 and a pin 44 disposed therebetween. The detent 42 is pivotally mounted upon the pin 44 and has a recess 50 for engaging a latching bar 48. Further, the spring 46 is disposed between the assembly 14 and the detent 42 to bias the detent 42 in a clockwise direction (as seen in FIG. 1) and to secure the latching bar 48 within the recess 50. The latching bar 48 may be released by depressing the detent 42 (and therefore the spring 46) and the latching bar 48 to remove the bar 48 from the recess 50.

Referring now to FIG. 3, the upper assembly 12 includes side walls 52 having recess portions 53 for receiving a terminal board 58 upon which there is disposed one set of the contacts. A top wall 56 is secured to the side walls 52 as by suitable fasteners 54 which extend through the side wall 52 and the terminal board 58 to secure the terminal board 58 in place. Further, the terminal board 58 has a plurality of closely spaced openings 60 for receiving a set of contact assemblies 104. The cable 16 extends through an opening within the upper wall 56 and includes a plurality of wires 17 which are each connected to one of the contact assemblies 104 by a suitable process such as soldering. In order to protect the wires 17 from moisture, vibration, and shock, a sealing plug 62 having a plurality of openings 64 is inserted within the assembly 12 so that the wires 17 are disposed through the openings 64 to be connected with the contact assemblies 104.

The lower assembly 14 includes side walls 66 and a bottom wall 78 secured to the side wall 66 by appropriate fasteners 81. Further, the side walls 66 have recesses 67 for receiving a terminal board 68 for supporting a plurality of sliding terminal assemblies 90. More specifically, the terminal board 68 includes a base member 69 having projections 71 which are disposed within the recess portions 67 and are secured therein by the fasteners 81. The base member 69 includes a plurality of openings 74 into which the terminal assemblies 90 are disposed and a pair of retaining members 70 and 72 disposed on either side thereof for confining the assemblies 90. As shown in FIG. 3, the retaining members 70 and 72 are secured to the base member 69 by a plurality of simple fasteners such as screws 79. The cable 20 includes a plurality of wires 21 which are disposed through the wall 66 and are connected to each of the terminal assemblies 90. More specifically, each of the wires 21 is fed through an opening 77 within a sealing plug 76 which serves to protect the wires 21 against moisture, shock, and vibration.

During the engagement and disengagement of electrical contacts, electrical discharges may occur between the spaced contacts. If these discharges were to occur in a combustible atmosphere, there would be a great probability of igniting this atmosphere. In order to prevent such explosions, there is provided a sealing ring 80 which is spring biased by springs 82 in a vertical direction (as shown in FIG. 3). The sealing ring 80 extends above the assembly 14 to engage the upper assembly 12 before the mating contacts engage. As the assemblies 12 and 14 are brought together, the sealing ring 80 is forced downward against the springs 82 thus shielding the terminal

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assemblies 90 and 104 from the surrounding atmosphere. More specifically, the sealing ring 80 fits into a recess 83 formed by the terminal board 68 and side walls 66 and is held therein by a plurality of stops 86 which project from the side walls 66 into corresponding guide slots 84. The position of the stops 86 and the length of the guide slots 84 determine the extent of movement of the sealing ring 80.

Referring now to FIG. 4, there is shown a detailed view of the sliding terminal assembly 90 mounted upon the lower assembly 14 and the stationary terminal assembly 104 disposed upon the upper assembly 12. The stationary terminal assembly 104 includes a terminal 103 which is inserted within the opening 60 of the terminal board 58. The terminal 103 has an enlarged portion 107 which is disposed within a recess 61 and which has a contacting surface 106 disposed to abut the terminal assembly 90. The terminal 103 is secured to the terminal board 58 by a washer 108 which is fastened to one end of the terminal 103 as by soldering.

The sliding terminal assembly 90 includes a terminal member 92 having an extending portion 91 which is disposed through an opening 73 disposed within the retaining member 72. The terminal member 92 has an enlarged portion 94 which abuts against one side of the retaining member 72 and a washer 96 which is secured as by soldering to the extending portion 91 to thereby secure the terminal member 92 upon the retaining member 72. Further, the terminal member 92 has a projecting portion 93 upon which there is secured a spring 98 as by welding to firmly mount the spring 98 upon the terminal member 92 and to insure a good electrical connection therebetween. The terminal assembly 90 includes a plunger contact 100 which is upwardly biased (as shown in FIG. 4) by the spring 98. The plunger contact 100 includes an enlarged portion 101 which abuts against the retaining member 70 and a contact portion 102 which extends through an opening 76 within the retaining member 70 to make contact with the contact surface 106 of the terminal 103. Further, the plunger contact 100 has a projecting portion 109 to which the spring 98 is firmly secured as by welding. The diameter of the opening 76 and the thickness of the retaining member 70 are accurately controlled to insure that the movement of the contact portion 102 is confined to a direction substantially perpendicular to the contact surface 106 of the terminal 103. If the opening 76 becomes too large, it may wobble as it is being depressed and may be "cocked" against the sides thereof. The spring 98 may be made of beryllium copper and be allowed to deflect about $\frac{1}{16}$ inch during engagement so that the contact portion 102 would exert about $\frac{1}{4}$ pound of compressive force against the surface 106. Illustratively, the terminal assemblies 90 could be spaced from each other by a distance of approximately $\frac{3}{16}$ of an inch and disposed in a regular array with approximately 25 contacts disposed within one square inch.

In one particular embodiment of this invention, one of the terminal contacts was made of niobium diselenide and the other contact was made of silver. These contact materials have demonstrated that they can withstand in vacuum a high shearing action with no noticeable damage to the contact surfaces. Referring to FIG. 4, it is noted that contact surface 106 is planar whereas the contact portion 102 presents a spherical surface. It is an important aspect of this invention that the contact configuration provides sufficient contact area with a controlled minimum of sliding during engagement. Alternatively, the abutting surface 106 as well as abutting surface 102, may be spherical. Further, the sealing members 18 and 22 may be made of silicone rubber whereas the terminal boards and the other dielectric members may be made of a suitable insulating material such as polyamide or Teflon (a trademark for a tetrafluoroethylene polymer of the Du Pont 6). The enclosure including the side walls and the

top walls may be made of a silver plated aluminum and the springs, pins and bar members may be made out of an austenitic stainless steel. The other members of the terminal assembly made may be of beryllium copper. In addition, the various joints of the device may be lubricated with a molybdenum disulphide.

It is an object of this invention that when the levers 24 are rotated in a counterclockwise direction (as seen in FIG. 1) that an upward or vertical force and a shearing or horizontal force is exerted through the pin 34 upon the upper assembly 12. Referring now to FIG. 5A, the operation of the mechanism of this invention will now be explained. The spring 98 forces the plunger contact 100 upward so that the terminal 103 and the plunger contact 100 abut each other respectively at their contact surfaces 106 and 102. Significantly, the terminals or contacts of this invention are of the non-reentrant or abutting variety which make contact with each other along a point or limited surface which is preferably as planar as possible. The use of abutting contacts is desired where a shearing force is applied to the contact surfaces. If a lateral or transverse shearing force was applied to contacts which were fitted together, the shearing force would be unable to move the contacts with respect to each other thus possibly damaging the contacts. As mentioned above, the plunger contact 100 is substantially confined to a motion along a path which is substantially perpendicular to the contact surfaces 102 and 106. Further, as the lever 24 is moved in a counterclockwise direction, the upper assembly as well as each of the stationary terminal assemblies 104 and terminals 103 will be moved upwardly along an arcuate path designated by the number 110. Referring to FIG. 5A, there is shown a point P about which the arcuate path 110 is rotated. Further, the point P is located in a plane designated by the numeral 112 and which may be defined as that plane which is substantially perpendicular to the direction in which the plunger contact 100 is confined and passing through a point on this line coinciding with the contact surfaces 102 and 106 when the respective terminals 100 and 103 are in a fully engaged condition (i.e. with the springs 98 depressed).

Thus, in operation when the upper assembly 12 is moved along the arcuate path 110 by the levers 24, a first motion component identified by the letter B is directed in a vertical direction from the terminal 103 and a second motion component identified by the letter A is directed along a horizontal path within the plane 112. The motion of the component of the upper assembly 12 identified by the letter A exerts a force which acts to break the possible welds between the terminal 103 and the plunger contact 100. In a preferred embodiment of this invention, the terminals 103 are moved through an arcuate path having a center point P which is in the plane 112. As a result of such an arrangement, the relatively large upward motion of the terminal 103 imparts a relatively small horizontal motion of the terminal 103. Thus, a mechanical advantage is realized and a nominal upward force exerted upon the terminal 103 will result in a large horizontal shearing force exerted upon the terminals 100 and 103. As shown in FIG. 5A, the vertical and horizontal components of the force exerted on the contacts may vary. At the instant of starting when the contact surfaces 102 and 106 lie in the plane 112, The ratio of the upward component to the horizontal component is theoretically infinite and there results in practice a high mechanical advantage for shearing the contact surfaces. Further, since the plunger contacts 100 are firmly supported within the openings 76, the shearing force as developed by the lever is positively exerted upon the contact surfaces 106 and 102. In one particular embodiment of this invention, the pins 32 and 34 were spaced $\frac{3}{8}$ of an inch apart; as a result, vertical motion of $\frac{1}{8}$ inch apart at the upper assembly 112 resulted in a horizontal portion of only .038 inch thereby achieving a mechanical advantage of over 3 to 1 at the end of the movement of the levers 24. It is

noted that an additional mechanical advantage is achieved due to the manner in which the levers 24 act upon the upper assembly 12. More specifically, a force exerted upon the end of the handle 26 acts through a moment arm whose length is substantially equal to the length of the handle 26, whereas the moment arm which acts upon the pin 34 is only of a length equal to the distance between the pin 32 to the cam portion 30.

In order to maximize the mechanical advantage of the force exerted upon the levers 24, the point P about which the arcuate path 110 rotates is placed in the plane 112. If the point P is displaced from the plane 112, the mechanical advantage and thus the forces exerted upon the terminal 103 of the electrical contact 100 would be decreased. More specifically, if the point P is displaced from the plane 112, a vertical motion along the arrow B would result in a relatively greater horizontal motion in the direction of the arrow A, and as a result the mechanical advantage would thereby be decreased. It may be understood that a large mechanical advantage is achieved when a relatively large vertical motion of the contact 103 will result in a relatively small horizontal motion. It is a significant teaching of this invention that the point P of rotation may not be displaced more than 45° in either direction from the plane 112 as measured from the point of contact between the terminal 103 of the contact 100 (i.e. when the contacts are engaged in a depressed condition). As the point P is removed from the plane 112, the mechanical advantage derived from this leverage system will be decreased to a point at a displacement of 45°, where the mechanical advantage becomes unity.

Referring now to FIG. 5B, the operation of an electrical connector having a plurality of mating contacts will be considered. More specifically, the contact assemblies 104 and 90 may be disposed in an XY matrix which is disposed symmetrically within the assemblies 12 and 14. Further, it may be understood that there are two levers 24 which are rotated about an axis defined by a line running through the center of the pins 32. It is desired that when the levers 24 are rotated in either direction that the cam surfaces 28 and 30 abut the pin 34 so as to apply a substantially equal pressure upon each of the contacts 103 or 100. In order to ideally accomplish this object, the line as defined by the pins 34 should intercept the line as determined by the centers of pressure. The term "center of pressure" as applied to electrical connectors may be defined as that point upon which a force may be applied with the result that substantially equal pressure will be exerted upon each of the electrical contacts associated with the connector. It may be understood that there may be several centers of pressure which in this context define a line. By placing the pins 34 upon a line which intercepts a center of pressure, the motion imparted to the upper assembly 12 by the lever 24 will impart a motion to each of the contacts 103a to 103e along arcuate paths 110a to 110e which are substantially identical with each other. In a manner as discussed above, the pins 32 should be so placed that the points of rotation of each of the arcuate paths 110a to 110e will be within $\pm 45^\circ$ of the plane 112. Further, in order to insure that the force exerted by the lever 24 through the pin 32 will be positively applied to each of the contacts 103, the pins 32 are also preferably placed within the plane 112. If the pins 32 were placed above the plane 112 by a significant distance, the shearing component of the force so applied would be applied through various moment arms to the contacts 103 thereby possibly resulting in an unequal and uneven shearing force being applied to different contacts. Though it is preferred that the pins 34 be placed within the plane 112, it is noted that in some cases involving a smaller number of contacts under various circumstances, that the pins 34 may be displaced to some degree from the plane 112 while still obtaining the desired shearing force.

In order to bring the contact assemblies 104 and 90 into engagement, the levers 24 are rotated in a clockwise

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direction (as seen in FIG. 1) thereby engaging the cam surfaces 28 against the pins 34. As the upper assembly 12 is being forced downward by the lever 24, the sliding ring 80 engages the upper assembly thereby preventing possible combustion of the surrounding atmosphere due to electrical discharges between the closing contacts. As the upper assembly 12 is driven toward the lower assembly 14, the ring 80 is pressed downward against the springs 82 and eventually the terminals 103 and the plunger contacts 100 engage with each other. As the terminals 103 are being pressed downward, they are also being forced in a horizontal direction to thereby wipe this contact surface 106 across the contact surfaces 102 of the plunger contacts 100. As a result of this motion between the contact surfaces, any contaminants that may have collected on these contacts will be removed. Finally after the contacts have been engaged, the latching bar 48 associated with the handles 26 will catch within the recess 50 of the detent 42 thereby holding the levers 24 in the position shown in FIG. 1 and thereby locking the assemblies 12 and 14 together.

When it is desired to disengage the contacts the detent mechanism is released by pressing downward on the latching bar 48 and inward upon the detent 42 thereby compressing the spring 46 and releasing the latching bar 48. Then the handles 26 of the levers 24 are rotated in a counterclockwise direction (as seen in FIG. 1) with the cam surface 30 engaging the pins 34. As a force is exerted by the cam surface 30 against the pin 34, the upper assembly 12 and each of the contacts 103 are moved along the arcuate path 110. As explained above, a large mechanical advantage is achieved in accordance with the teachings of this invention to impart a high shearing force upon the contact surfaces to thereby break any possible welds between the contacts.

Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. An electrical connector comprising first and second assemblies having respectively a plurality of first and second contacts, said first and second contacts abutting each other along a limited contact surface, means for biasing and confining the movement of said first contacts along a path perpendicular to the contact surface of said second contacts, and lever means pivotally mounted on one of said assemblies to impart to the other of said assemblies a motion having a first component along said perpendicular path to disengage said assemblies and a second component transverse to said path to exert a high shearing force upon said contacts.

2. An electrical connector as claimed in claim 1, wherein said lever means is pivotally mounted at a point disposed substantially within a plane defined by the contact surface when the first and second contacts are engaged.

3. An electrical connector as claimed in claim 1, where-

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in said lever means engages said other assembly to impart an arcuate motion to each of the contacts of said other assembly which is substantially similar.

4. An electrical connector as claimed in claim 3, wherein said pluralities of first and second contacts are adapted to engage each other in a plane, said position of said lever means being so disposed that the point of rotation of said arcuate path imparted to said contacts of said other assembly is within 45° of a said plane as measured from the point of interception of said arcuate path and said plane.

5. An electrical connector as claimed in claim 1, wherein said lever means is adapted to impart an arcuate motion to said other assembly about a point located in a plane which is perpendicular to the plane defined by said contact surface, said point located in said perpendicular plane at a location within the planar area defined by lines extending in said perpendicular plane from the point of interception of said arcuate path and said contact surface at angles $\pm 45^\circ$ from said contact surface.

6. An electrical connector as claimed in claim 5, wherein said lever means includes first and second cam surfaces adapted to engage a member affixed to said other assembly for respectively engaging and disengaging said first and second assemblies.

7. An electrical connector as claimed in claim 6, wherein said lever means includes first and second members pivotally mounted upon said first assembly, a bar interconnecting said first and second members, and detent means engaging said bar for locking said first and second assemblies together.

8. An electrical connector as claimed in claim 6, wherein said member is disposed substantially within the plane defined by said contact surface.

9. An electrical connector as claimed in claim 1, further including a cylindrical enclosure which is biased within said connector assemblies to isolate the contacts of said assemblies from hazardous atmospheres external to said connector during contact engagement and disengagement.

10. An electrical connector as claimed in claim 1, wherein said first and second contacts are disposed in sealing material which minimizes the adverse affects of moisture, vibration, and shock.

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MARVIN A. CHAMPION, Primary Examiner

P. A. CLIFFORD, Assistant Examiner

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