

May 18, 1948.

R. S. OHL

2,441,590

TRANSLATING DEVICE

Filed March 24, 1944

4 Sheets-Sheet 1

FIG. 1

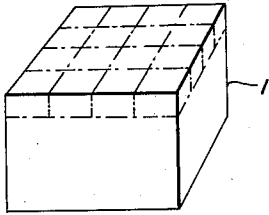


FIG. 2

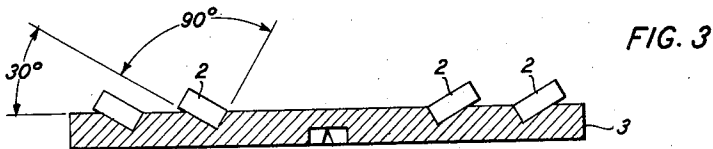
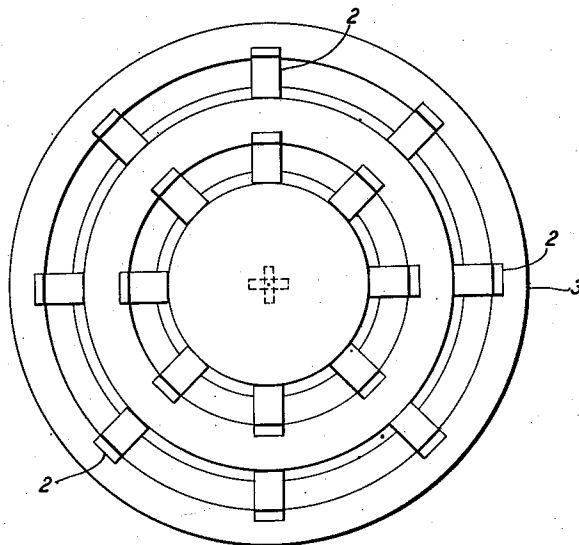


FIG. 4



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FIG. 5

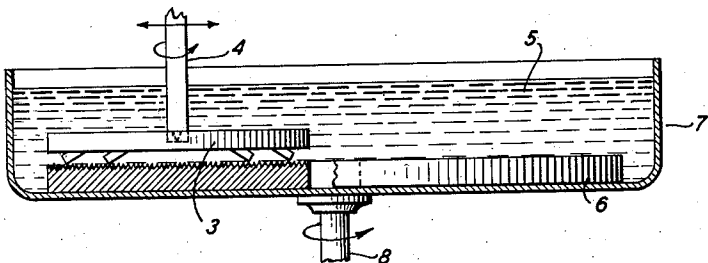


FIG. 6

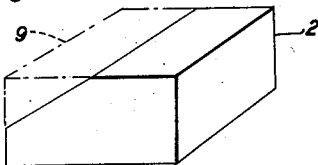


FIG. 7

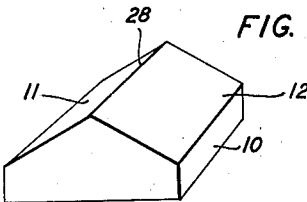


FIG. 8

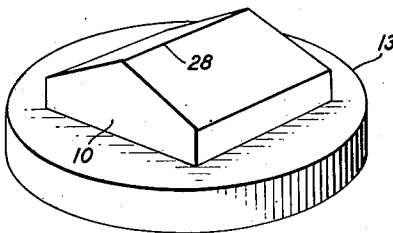
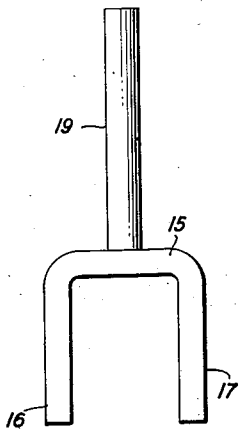


FIG. 9



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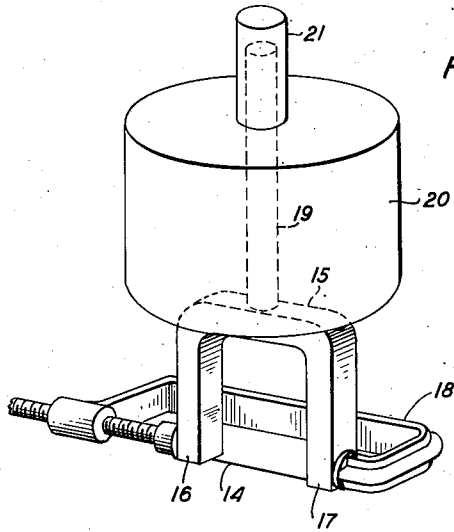


FIG. 10

FIG. 11

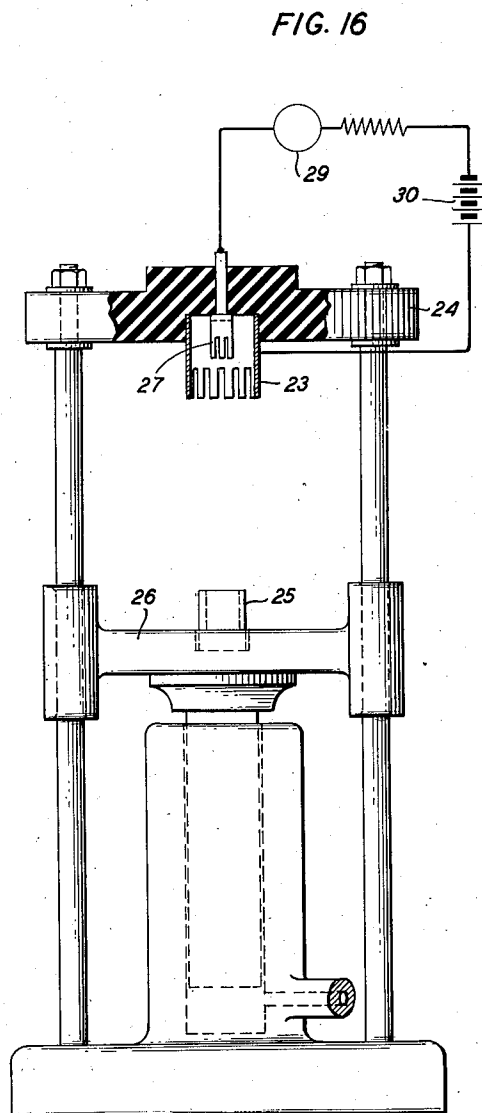
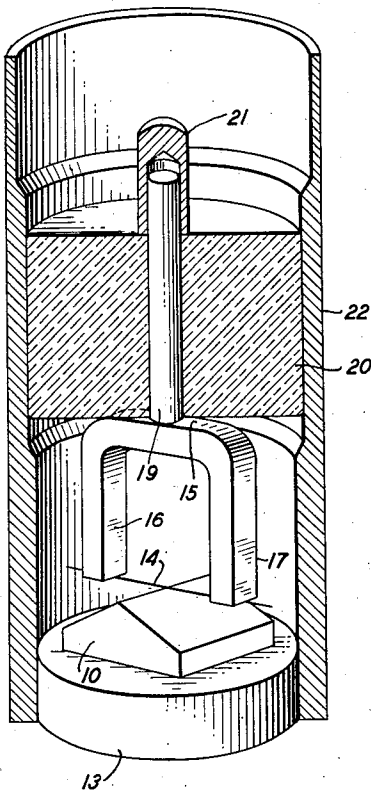


FIG. 16

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FIG. 12

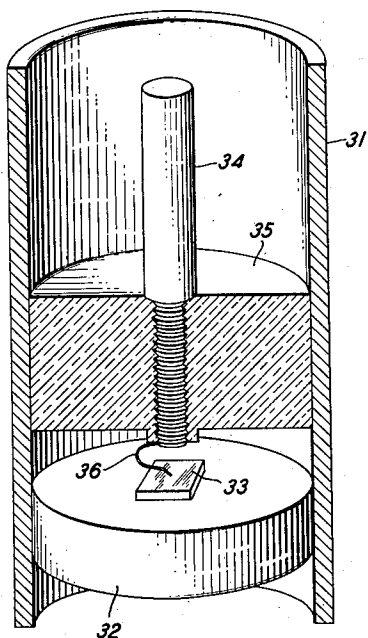


FIG. 13

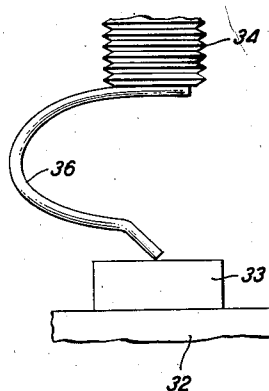


FIG. 14

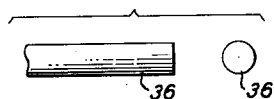
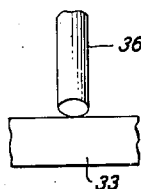


FIG. 15



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UNITED STATES PATENT OFFICE

2,441,590

TRANSLATING DEVICE

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Application March 24, 1944, Serial No. 528,009

6 Claims. (Cl. 250-31)

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This invention relates to electrical translating devices and particularly to devices of this kind having small areas of contact between different materials.

The objects of the invention are to reduce the contact area of electrical translating devices; to maintain a high degree of contact stability; to shield and safeguard the delicate parts from injury or impairment; to improve the uniformity of the electric circuits in which they are used; to simplify the structure; and to secure other improvements in these devices and in methods of making them.

One of the problems involved in the use of ultra-high frequencies for signaling purposes in the radio and allied arts has been the development of a satisfactory translating device for detecting, converting or otherwise translating signal waves having frequencies of the order of a few centimeters. Thus far the most promising solution of this problem has been a translating or rectifying device of the point-contact type. In one form, a fine tungsten wire is mounted so that its free end engages the surface of an element having suitable rectifying properties, such as a crystal of silicon. More specifically, rectifiers of this kind have been made by grinding one end of a fine tungsten wire (.005 inch in diameter) to a point, carefully assembling the elements to bring the ground point into resilient contact with the surface of the crystal so as to flatten the pointed end of the wire until the contact engagement between the wire and the crystal surface becomes a small finite area.

While these devices have given good results with wave-lengths in the neighborhood of 10 centimeters, the further extension of the signaling frequencies into the region of 1 centimeter wave-lengths imposes requirements on the rectifying contact that are very difficult to realize. One of the difficulties is to obtain a contact point which is sufficiently small in area; another is to obtain the necessary contact pressure and the necessary resiliency to hold the contact in a stable condition.

According to the present invention these difficulties are overcome by an improved translating device in which a novel contact-spring structure is employed to obtain a greatly reduced contact area and to maintain in said contact a high degree of electrical stability, and in which the contact-forming parts are closely and compactly mounted within a protective housing that shields them from exposure to physical or electrical shocks.

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More specifically, the device in one of its forms comprises a rectifying crystal of silicon in the shape of a wedge, the apex edge of which is a sharply defined line, and a metallic contact element of extremely fine wire of tungsten or other suitable material suspended under tension across the prongs of a bow member, these parts being so assembled in the structure that the tensioned contact wire engages the apex line of the wedge to form a stable rectifying contact of extremely small dimensions.

In another embodiment of the device the desired small stable contact area is attained by using a short length of fine wire with its free end ground at right angles to its length to present a normal cross-sectional circular area and bending the wire in a single loop so that only a small arc of the circumference at the free tip end of the wire bears on the surface of the rectifying crystal. The short loop thus formed in the contact wire gives it some resiliency; yet it also affords a maximum of pressure on the contact point notwithstanding the extreme fineness of the wire itself.

Still another difficulty experienced with rectifiers of this class is the susceptibility of the contact point to impairment or permanent damage from electric discharges to which they may be subjected during handling or in actual use, this danger being one that increases materially as the area of the contact is decreased. This disadvantage, however, is overcome through a further feature of the invention by means of a device of the character above-described in which the parts are assembled within a small metal cylinder which serves as a combined mounting and electrical shield.

Another feature of the invention is a method of preparing the crystal rectifying elements which comprises cutting small rectangular slabs from a fused ingot, grinding one surface of each slab to the shape of a wedge having a predetermined apex angle, and polishing the ground surfaces of the element until the ridge or apex of the wedge is a thin uniform line.

These and other features of the invention will be described more fully in the following detailed specification.

In the drawings accompanying the specification:

Fig. 1 illustrates a block of fused silicon having a high degree of purity;

Fig. 2 is a small slab or wafer cut from the block of Fig. 1;

Figs. 3 and 4 are cross-sectional and plan views

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of a chuck to which a plurality of the silicon wafers are affixed for grinding and polishing;

Fig. 5 illustrates the grinding and polishing mechanism;

Figs. 6 and 7 are perspective views of the silicon wafer, greatly enlarged, illustrating the different stages in the grinding and polishing process;

Fig. 8 is a perspective view showing the finished silicon element mounted on a metallic base;

Fig. 9 shows a pronged member or bridge for supporting the contact wire;

Fig. 10 is a perspective view showing the assembly of the bridge member and ceramic insulating element;

Fig. 11 is a cross-sectional view of the assembly of one form of the translating device;

Fig. 12 is an assembly of another form of the device;

Figs. 13, 14, and 15 are enlarged details of the contact elements of the modification of Fig. 12, and

Fig. 16 is a mechanism for performing the assembling operations.

Satisfactory rectifiers for use with waves of 10 centimeters or more have been made by bending or shaping the fine tungsten wire (.005 inch diameter) in a plurality of loops to give it more resilience and by fixing it with the pointed end in engagement with a crystal. However, the area of the rectifying contact thus formed is too large for best results with wave-lengths in the neighborhood of 1 centimeter. If the size of the contact wire is reduced in an effort to decrease the contact area, the unit becomes unstable because of the consequent reduction in the pressure which the resilient contact wire is capable of exerting against the surface of the crystal. Moreover, the bends introduced in the contact wire to obtain the desired spring pressure at the contact surface are also the source of substantial electrical inductance particularly at the high frequencies to which these devices are subjected. In applicant's device it is possible to effect a large reduction in the size of the contact wire and consequently in the size of the rectifying contact area without sacrificing the spring pressure necessary to maintain stability. In one embodiment of the invention this desirable end is achieved with the use of a straight contact wire which adds substantially no inductance to the electrical circuit of which it is a part. In another form it is accomplished by using a short contact wire having a single loop therein and shaping the tip of the free end so that only a small part of its area engages the surface of the crystal. And, as above-noted, the component parts of these rectifiers are mounted and housed within a metal tube which shields the contact point against extraneous electrical influences and protects it against static discharges from neighboring objects, particularly while it is being handled.

Referring now to the drawings, the first step in the manufacture of the rectifier herein disclosed is the preparation of an ingot of silicon having a high degree of purity. One method by which the silicon material may be prepared is disclosed in the application of J. H. Scaff, Serial No. 386,835, filed April 4, 1941, issued as Patent 2,402,582, June 25, 1946. After the ingot has been prepared, a block 1 of desired dimensions and also of desired electrical characteristics is shaped from the ingot. Next the top surface of a slab, cut from the block 1, is plated with

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nickel or any other suitable metal, following which wafers 2 are cut to the proper dimensions from the slab, a diamond saw being used for this purpose. Although the dimensions of the wafer 2 may vary to suit requirements, good results have been obtained when the large surface of the wafer is a square $\frac{1}{8}$ inch on the side and the thickness of the wafer is $\frac{1}{16}$ inch.

The next step in the process, when preparing units for rectifiers of the form shown in Fig. 11, is to grind the wafers 2 into the shape of a wedge as illustrated in Fig. 7. To this end a plurality of these wafers are cemented into notches formed in the surface of a chuck 3. These notches are cut in two or more concentric rows, and the angles which they make with the surface of the chuck determines the apex angle of the finished silicon wedge. Although these angles may vary as desired, the notches illustrated in the drawing are cut at 30 degrees and 60 degrees. The rectangular wafers are cemented into these notches by means of any suitable adhesive material such as shellac, care being taken to fix the wafers in the notches with the nickel-plated surfaces down, thus exposing the unplated surfaces to the grinding action.

Thereupon the chuck 3 is associated with the driving shaft 4 (Fig. 5) and immersed in a grinding bath 5 to bring the silicon wafers 2 into contact with the grinding lap 6. The lap 6, which may be of any suitable metal contains a series of grooves and rests on the bottom of the cup 7 with which it is rotated by the driving shaft 8. The lap 6 is charged with suitable abrasive materials, such as boron carbide, for cutting away sections of the silicon wafers. The mechanism is designed to rotate the lap 6 and the chuck 3 in the same direction but at different speeds and is also designed to impart an oscillatory movement to the chuck 3 while it is being rotated. During the first part of the grinding operation a section 9 of each wafer 2 is cut away at the predetermined angle as illustrated in Fig. 6. When this has been accomplished the grinding lap 6 is replaced by one charged with a polishing abrasive, such as sappharine, and a polishing bath is placed in the cup 7. The polishing operation now proceeds until the first roughed surfaces of the wafers are brought to a high optical finish. Next, the wafers are removed from the chuck 3 and again cemented thereto in the reverse position. The second part of the grinding operation is then performed, during which a similar section is cut away on the opposite side of each wafer giving it the desired wedge shape as illustrated in Fig. 7. Finally the polishing operation is repeated on the opposite roughed surfaces of the wafers. These polishing steps are very important since they determine in large measure the performance of the rectifying device. By giving the sloping surfaces 11 and 12 a high optical finish the intersection of these surfaces becomes a thin line which is extremely uniform and free from irregularities such as protuberances and depressions.

Following the polishing operation each one of the wedges 10 is soldered to a brass mounting base or plug 13, the nickel-plated surface of the wedge serving to facilitate the soldered joint.

The spring wire contact unit of the rectifier, shown in Fig. 10, comprises a metallic bow or bridge member 15 mounted in a cylinder 20 which may be of ceramic or other insulating material, and supporting a fine wire 14 of tungsten or

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other suitable material, having a diameter which is preferably as small as .001 inch. To assemble the contact unit, the shank 19 of the bow member 15 is driven with a force fit into the central hole of the ceramic cylinder 20 and a cap 21 of silver or other suitable metal is welded on over the projecting end of the shank to hold the bow 15 securely in position. Following this the tungsten contact wire 14 is welded to the times 16 and 17 of the bow 15. The requisite degree of tension is secured in the contact wire 14 by flexing the times 16 and 17 of the bow inwardly by means of a clamp 18 while the ends of the wire 14 are welded thereto.

The outer shell or housing of the rectifier is made from a section of metallic tubing of coin silver or other suitable metal. After being cut to the proper length, the housing tube 22 is drilled to a plurality of graduated internal diameters as illustrated in Fig. 11 of the drawing.

The several parts of the rectifier are assembled by means of the hydraulic press mechanism illustrated in Fig. 16. The first step in the assembly is to force the ceramic unit shown in Fig. 10 into its predetermined position within the cylinder 22. To do this, the cylinder 22 with its large opening downward is slipped into the slotted receptacle 23 until it is seated firmly against the bottom of the opening in the insulating bar 24 where it is held by the resilience of the receptacle. The ceramic unit is placed on the cup 25 with the bow member 15 extending upwardly and with the ceramic cylinder 20 disposed concentrically with respect to the large opening in the bottom of the cylinder 22. The hydraulic jack is now operated to force the ceramic cylinder 20 with a tight fit into a predetermined position in the intermediate section of the tube 22. One convenient way of determining the correct position of the ceramic cylinder within the housing tube 22 is to proportion the parts in such a manner that the movable support 26 in its upward movement reaches the bottom end of the tube when the ceramic cylinder 20 advances to the desired predetermined position within the tube. The jack is now released and the second step in the assembly is then performed.

To this end the tube 22 is withdrawn from the receptacle 23, turned end for end and again inserted in the receptacle. This time the welded cap 21 slips into the slotted jack 27 as the corresponding end of the tube 22 comes to rest against the bottom of the opening in the bar 24. The purpose of engaging the cap 21 with the jack 27 is to obtain an electrical connection between the contact wire 14 and an external circuit to facilitate the assembling. Thereupon the brass plug 13 is placed on the cup 25 in such a manner that the apex line 28 of the silicon wedge 10 is accurately disposed at right angles to the contact wire 14. The hydraulic jack is again operated, forcing the brass plug 13 into the lower open end of the tube 22 and causing the apex ridge of the wedge to approach the contact wire 14. Since these parts are now concealed from view, it is necessary to devise some means for determining when the ridge line engages the wire 14 and establishes the requisite degree of pressure thereon. One method is to connect the silicon wedge and the contact wire in an electrical circuit with a suitable instrument 29 and a source of current 30. When the silicon wedge is advanced to the point where it engages the resilient wire 14 with the requisite force, as indicated by the information obtained from the instrument 29,

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the hydraulic jack is released, and the assembled rectifier is removed.

Referring now to the alternative construction shown in Figs. 12 to 15, the housing shield for this form consists of a hollow cylinder 31 having a uniform internal diameter. The cylinder 31 may be made either of steel or of beryllium copper. When steel is used, the cylinder may be given a thin coat of tin. If beryllium copper is used, the cylinder may be left unplated or it may be plated with gold.

The crystal unit comprises a solid cylinder 32 of brass, plated with tin if desired, to which a polished silicon wafer 33 is affixed. The wafers 33 for this type of rectifier may be cut from the block 4, preferably to a thickness of about $\frac{1}{64}$ inch. Since, however, the contact surface of the wafer is a plane and parallel to the base, the polishing operation is accomplished by cementing the wafers to a chuck, similar to the chuck 3, but having a plane surface. Thereupon the chuck, having a plurality of these wafers cemented to the surface thereof, is introduced in the polishing bath 5, and the wafers are polished to a high finish on the lap 6.

The spring wire contact unit of the rectifier comprises a metallic pin 34 preferably of nickel, an insulating cylinder 35 and a short length of tungsten contact wire 36. A section of the pin 34 is reduced in diameter and threaded or corrugated, and the insulating cylinder 35 is then molded around this section of the pin. Good results are obtained by the use of a molding material composed of an intimate mixture of quartz powder and a highly pure phenolic resin. The contact wire 36, which is of pure tungsten, is about .002 of an inch in diameter, and the contact end thereof is ground to a plane circular surface normal to the axis of the wire. The opposite end of the wire 36 is then spot-welded to the end of pin 34, as seen in Fig. 13, and the wire is shaped in a single loop with the free end bent at such an angle that only a portion of the circumference of the tip of the wire engages the surface of the silicon crystal 33 to form the rectifying contact area. With this contact wire formation a substantial pressure may be obtained on a small contact area.

The crystal supporting cylinder 22 and the contact wire assembly, including the insulating cylinder 35, are driven into opposite ends of the housing tube 31 where they are held by a force-fit securely in their required positions. These elements may be assembled in the housing tube 31 by means of the hydraulic press shown in Fig. 16, and suitable electrical circuit means may be employed to determine when the contact wire 36 has engaged the surface of the silicon crystal 33 with the requisite degree of pressure.

The advantages of these translating devices, which were mentioned at the beginning of the specification, will now be more apparent. A rectification contact of extremely small area is obtained without sacrificing stability. The electrical circuit formed by the silicon element and the tungsten wire is extremely simple, with inductive effects reduced to a minimum. The rectification contact is protected physically and electrically by the housing tube which surrounds it, and in this connection it will be noted that the assembled unit may be handled freely without danger of touching simultaneously the outer shield and the central terminal, thus obviating the danger of static charges being discharged through the unit and damaging it. Finally the simplicity of the

assembly makes it attractive from the standpoint of cost and manufacture.

What is claimed is:

1. The combination in a translating device of a hollow metallic cylinder open at one end, a metallic base member supported in said cylinder and making electrical contact therewith, a rectifying element mounted on said base member within said cylinder, an insulating member supported in said cylinder and forming with said base member a closed chamber within said cylinder, a contact wire supported by said insulating member and making contact engagement with said rectifying element, and an electrical terminal for said contact wire extending through said insulating member and into the open end of said cylinder, said metallic cylinder serving as an electrical shield for said rectifying element and as a physical shield for said terminal.

2. A combination in a translating device of a metallic housing tube having an open end, a metallic base member supported in said tube and making electrical contact therewith, a rectifying element mounted on said base member within said tube, an insulating cylinder supported in said tube and forming with said base member a closed chamber within said tube, a contact wire supported on said insulating cylinder and making contact engagement with said rectifying element, and an electrical terminal for said contact wire extending through said insulating cylinder and into the open end of said tube, said tube serving as an electrical terminal for said rectifying element, as an electrical shield for said rectifying element and contact wire, and as a physical shield for the said electrical terminal of said contact wire.

3. The combination in a translating device of a metallic housing tube having an open end, a cylindrical metal base member forced into one end of said tube and held tightly in place therein, a silicon crystal rectifying element mounted on said base member within said tube, a cylinder of insulating material forced into said tube and held tightly in place therein, said metallic base member and said insulating cylinder forming a closed chamber within said tube, an electrical terminal extending centrally through said insulating cylinder from said closed chamber to the open end of the tube, and a contact wire secured to said electrical terminal within said chamber and making contact engagement with said rectifying element, said housing tube serving as an electrical terminal for said rectifying element, as an electrical shield for said rectifying element and contact wire, and as a physical shield for said electrical terminal and contact wire.

4. The combination in a translating device of a hollow metallic housing member, a metallic base member supported within said housing member and making electrical contact therewith, a trans-

lating element mounted on said base member, said element having plane surfaces intersecting to form an apex line, an insulating member supported in said housing member, a bridge member secured to said insulating member and extending in proximity to said translating element, and a fine contact wire stretched across said bridge member and attached thereto at its opposite ends, said bridge member serving to hold the contact wire under tension and in engagement with the apex line of said translating element to form a small contact area between said wire and said element.

5. The combination in a translating device of a metallic housing tube, a cylindrical metallic base member supported within said tube and making electrical engagement therewith, a translating element mounted on said base member, said element having two plane surfaces intersecting each other to form an apex line, a cylindrical insulating member supported within said tube, said metallic base member and said insulating cylinder forming a closed chamber within said tube, a bridge member secured to said insulating cylinder and disposed within said chamber, a contact wire stretched across said bridge member and attached thereto at its opposite ends, said bridge member serving to hold said contact wire under tension and in engagement with the apex line of said translating element to form a contact area between said wire and said element.

6. The combination in a translating device of an elongated metallic housing member having an open end, a metallic base member supported in said housing member and making electrical contact therewith, an insulating member supported in said housing member and forming with said base member a closed chamber within said housing member, a rectifying element mounted on said base member within said chamber, an electrical terminal supported by said insulating member and extending into the open end of said housing member, and a contact wire secured to said terminal and disposed within said chamber to make contact engagement with said rectifying element, said metallic housing member serving as an electrical shield for said rectifying element and as a physical shield for said electrical terminal.

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The following references are of record in the file of this patent:

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