Dec. 2, 1969 G. C. BALDWIN 3,482,091

ELECTRON TRANSPARENT SHIELD FOR SEPARATING REGIONS OF DIFFERENT FIELD INTENSITIES

Filed Jan. 6, 1966

Fig. 1.

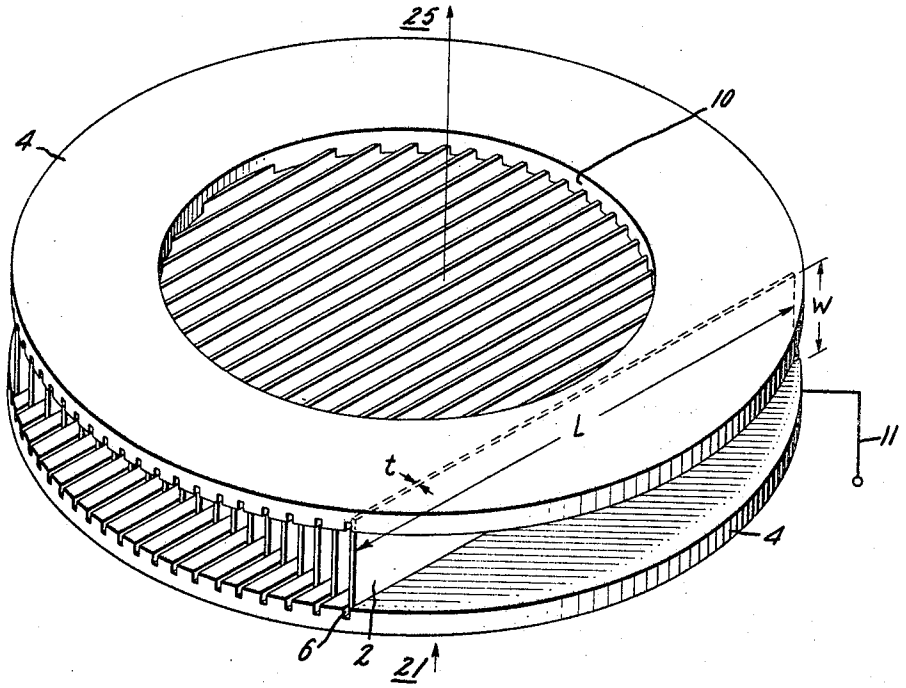
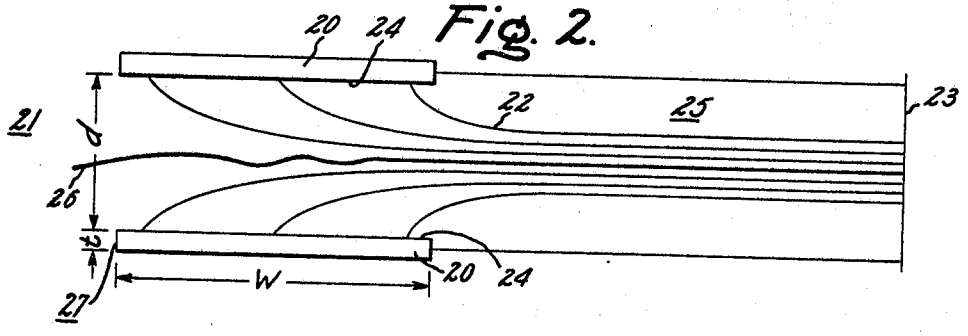



Fig. 2.



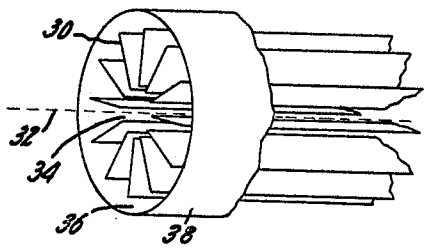




Fig. 3.

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United States Patent Office 3,482,091
Patented Dec. 2, 1969



3,482,091

# ELECTRON TRANSPARENT SHIELD FOR SEPARATING REGIONS OF DIFFERENT FIELD INTENSITIES

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Filed Jan. 6, 1966, Ser. No. 519,158
Int. Cl. H01j 37/26, 39/34; B01d 59/44
U.S. Cl. 250—49.5 2 Claims

## ABSTRACT OF THE DISCLOSURE

An abrupt transition shielding device for permitting electron passage therethrough while separating a strong electric field from a field-free region. The shield is constructed of an array of thin equipotential members arranged in a particular pattern, either parallel to each other and to the incident electron path, or a cylindrical array of members arranged radially. The spacing between the members is completely unobstructed along the electron flight path to prevent any scattering of electrons especially in the low energy range.

My invention realtes to a novel electrical shielding element for separating regions of unequal electric field intensities, and more particularly, to a shield which permits electrons to pass therethrough while separating a region of strong electric field from a substantially field-free region.

In many fields of modern technology it is desirable to maintain a field-free region adjacent to a region which has an electric or magnetic field therein. The problem becomes more difficult when it is desired for electrons to travel from one region, especially the field-free one, into the other, a high electric field region, while maintaining the fields in their desired relationship. The problem arises in electronic devices, such as exemplied by the electron time-of-flight spectrometer disclosed in concurrently filed application Ser. No. 519,024 entitled "Method and Apparatus for Measuring Velocity of Low Energy Electrons" by George C. Baldwin, the inventor of the present application, and which is assigned to the assignee of the present application. In this spectrometer, slowly moving low energy electrons travelling in a field-free region (an area of substantially no electric or magnetic field) over a measured flight path, pass into a region having an intense electric field of such intensity that sufficient energy is imparted to them in a short distance for them to actuate an electron detector so as to be properly registered and counted. As an essential requisite for proper operation, transition between the field-free drift region and the adjacent electric field region must be abrupt, in order that the measured flight path be precisely defined. Also, the abruptness is necessary so that the electron is given the energy needed to effect registration in a time short in comparison with its time of flight over the measured path. Both the distance and the time required by the electron to traverse the path are then accurately known so that the electron velocity can be precisely determined. An additional problem which then arises is that of providing a field configuration which will not so deflect the paths of the electrons travelling from the field-free region into the high field region so as to prevent their reaching the detector. One particular shielding device commonly employed for separating two regions of unequal electric field intensity uses grids of parallel wires that have circular cross sectional areas, which are evenly arrayed in one or more parallel planes, and maintained at an electric potential appropriate to establish the required electric field



conditions on each side thereof. Since, the electric field surrounding each wire is, in its immediate vicinity, perpendicular to its surface, then an electric field which is uniform at some distance from the grid but which terminates on circular cross-sectional wire members becomes in the vicinity of the wire member, a radial field with its lines of force converging upon the element from all sides in the vicinity of the wire. Thus, reverse and tranverse field components exist in the electric field near the wire.

Even perfectly directed slow electrons trying to pass through such a non-uniform electric field will be scattered by such a field, especially by the reverse and the transverse components of the field. The scattering is to an extent dependent on the energies of the electrons. Very slow electrons, which are often those desired to be measured, are the ones most readily scattered or turned back by the transverse and reverse components of this electric field. The scattering and dispersion, especially of the slow energy electrons occurs to such an extent that no useful function can be performed with the low energy electrons. It is desirable that the shielding element transmit even low energy electrons without scattering them. It is also useful for the shielding element to focus the electrons that pass therethrough, as in the case where a collector or detector is located on one side of the shield, the shielding element serving to focus the electrons to the most sensitive part of the detector for most effective operation thereof. The need then arises for a shielding element which separates regions of differing electric field intensities in such a manner that even though there is an abrupt transition, there is no significant mixing between the two fields, and slow electrons may thus readily pass through the shielding element to be directed in a desired manner.

The principal object of my invention is the provision of a novel electrical field separator that readily permits the passage of electrons therethrough.

Another object of my invention is the provision of such a separator that causes each electron that has passed through to follow a prescribed path, i.e., to focus the electrons.

Another object of my invention is the provision of such a separator that prevents mixing of the differing electric fields on both sides thereof.

A still further object of my invention is the provision of such a device which separates a high region from a field-free region.

In carrying out the objects of my invention. I provide a highly efficient shielding element that permits all electrons, even slowly moving ones, to pass through while separating regions of differing electric field intensity so effectively that there is an abrupt division between the fields with substantially no mixing therebetween. That is to say, the field intensity on the low field side is not appreciably increased by the presence of an intense field on the other side of the shielding element. The shield comprises an array of thin equipotential members or surfaces of electrically conductive material, each generated by the movement of a straight line. As one example, an array of thin rectangular slats are arranged parallel to each other and to a beam of electrons incident on the shield. The pattern of the electric field formed around and between the slats is such as to aid the electrons travelling through the shielding element into the region of higher electrical intensity. The direction of electrical force lines within the grid also tends to align the electrons in the desired flight path, the path parallel to the slats, if their incident flight paths differ slightly therefrom. The alignment thus serves to focus the electrons passing through the shielding element toward a particular object, such as an electron detector whereby the focussing serves to insure registration by the detector of all electrons pass-

ing through the shield, even very slowly moving low energy ones.

The attached drawing illustrates a preferred embodiment of my invention in which:

FIGURE 1 is a perspective view of the electron transparent separating shield of my invention.

FIGURE 2 is a cross-sectional diagrammatic side view of the path of electrons through the shield of FIGURE 1.

FIGURE 3 is a perspective view of a second embodiment of my invention.

In FIGURE 1 there is shown a perspective view of the shielding element of my invention showing a grid or array of planar surfaces in the form of slats **2**, and upper and lower annular plates **4** which hold the slats together in proper alignment. The slats **2** are thin flat strips of a planar configuration constructed of an electrically conductive material such as gold-plated molybdenum, which may be coated with colloidal graphite to obtain a more nearly uniform electric contact potential. The slats may be rectangular in shape, as illustrated, with a length dimension L much greater than the width W, but it will be understood that the rectangular configuration is merely one of many that successfully embody my invention. The length dimenion L is normal to the direction of electron flight which enters the shield from region **21**, and exits into region **25** as indicated by the arrows associated with numerals **21**, **25**.

The circular plates **4** positioned above and below the slats are provided to secure the slats in a desired parallel position. It should be understood that the means for retaining the slats in parallel position is not limited to two annular plates, but may, as further examples, comprise a single cylinder around the outer edges of the slats, or rectangular end plate members, depending upon the outline of the slat array in a plane normal to the direction of the aforementioned arrows. Suitable grooves **6** may be provided in plates **4** to insure that the slats remain in the desired position. Brazing, welding, or other suitable securing methods may be employed to bond the plates and slats together. Alternatively, nuts and bolts or rivets may be provided to accomplish the securing. Configuration of the plates **4** is preferably annular, i.e., circular with a circular opening **10** therein, but it is understood that depending on the intended application the plates would be shaped accordingly. The most important aspect of the plates is that they firmly secure the slats together in a parallel array without interfering with electrons traveling therethrough. The shield comprising the slat grid illustrated is intended for use with the spectrometer described in the aforementioned patent application, the grid being placed in a tubular member.

FIGURE 2 is a side view of two adjacent slats in FIGURE 1, and indicates the manner in which the lines of an electric field terminate on the slats of the grid of FIGURE 1. Substantially no electric field is present in region **21** of the grid. The lines of force **22** due to a high voltage applied to detector, or other member **23** run between member **23** and the faces **24** of the slats **20**, constituting a relatively intense electric field in region **25** of the grid. Since lines of force are always substantially perpendicular to the conducting surfaces which they contact, the lines of force extending between the surface of member **23** and surfaces **24** of slots **20** are perpendicular to both surfaces. In a typical application, for example in the electron time-of-flight spectrometer, a potential is preferably applied to the grid by means of conductor **11** suitably connected to plate **4** so as to bring it to the same voltage level as the region **21** from where the electrons enter the grid. Thus, there is no field produced between the grid and region **21**. Also, since the individual grid slats **20** are all at the same potential (equipotential), there is no field therebetween. Hence, the field that is set up between the grid and member **23** is caused solely by the potential difference between the two. Thus, the lines of the field extend only from a grid slat to member **23**, since these are the only surfaces which differ in potential. These lines are parallel and uniformly spaced near member **23**, that is to say, the electric field is uniform. In the space within two adjacent grid elements **20**, the electric field intensity grows weaker as the distance from the voltage source member **23** increases, thus any lines of force which extend to end **27** of the grid slats or beyond are so few as to be insignificant.

It is thus readily seen that all lines of force extend in directions such that they have one component perpendicular to surface **24** and another directed toward member **23**, without any components thereof being oppositely directed away from the surface of member **23**. This is the major problem with previous grids, especially wire ones, wherein some of the lines of force or components thereof extend for a slight distance in a direction away from member **23**, and thus electrons trying to pass through the grid are scattered by these opposed lines of force. My invention thus completely eliminated this problem of reversed lines of force. As an electron, shown by line **26**, enters the space between grid plates **20** it is acted upon by electric lines which direct it first toward the space midway between plates **20** and which then direct it toward member **23**. The directional effect of the lines of force is such that electrons that are slightly misdirected when entering the space between the plates will be properly aligned by the lines of the field, since the transverse components of this field are strongest near the plates **20** and vanish in the mid plane. Thus, the electrons are caused to oscillate transversely rather than to strike the grid plate **20** while the other component of this field is directed toward member **23** and continuously accelerates the electron thereto. In this manner, electrons are directed toward the mid-plane of the grid and emerge therefrom very nearly parallel to the intended path toward detector or other recording means **23**. Thus, a focussing action is readily achieved with the shielding element. The electric field configuration within the space between adjacent slat elements **20** may be described mathematically by the aid of Laplace's equation, well known in the theory of electric and magnetic fields. In all practically significant cases slot elements **20** are spaced apart by a distance $d$ short compared with their common width W, and it is found by the use of this equation that the two electric field components in the spaces between parallel slats **20** are very closely represented by equations of the form

$$E_x = E_o |\cos(\pi y/d)| \cos h(\pi x/d)$$

$$E_y = -E_o |\sin(\pi y/d)| \sin h(\pi x/d)$$

in which $x$ is a coordinate measuring distance parallel to the slats **20** from the plane of ends **27**, and $y$ is the coordinate measuring distance from the mid-plane of any adjacent pair of slats **20**, and $E_o$ is a constant determined by the magnitude of the potential applied to member **23**. The motion of an electron entering a field with this configuration can be computed by standard methods of particle dynamics, employing either numerical or analog techniques, and it can thereby be demonstrated rigorously that the trajectory **26** of an electron which is incident on the grid from region **21** is a curved path **26** which may be regarded as an oscillation with diminishing amplitude in the $y$-coordinate accompanied by a translation at increasing velocity in the $x$-coordinate, the oscillation in the $y$-coordinate taking place only while the electron is within the grid. It can also be vertified by inspection of the equation for the $x$-component of the electric field intensity, $E_x$, that this component is greatly attenuated by the grid if the width W of slats **20** is appreciably greater than the spacing $d$ of adjacent slats. Thus, if $W = 10d$, the electric field intensity at the mid-plane is less in space **21** than that in space **25** by a factor cosh $(10\pi)$. In general, width W is preferably at least 5 to $10d$, and the slat spacing $d$ is much greater than the slat thickness $t$. It should be emphasized that the spacing $d$ between adjacent

slats need not be equal for each pair of adjacent slats, but is so employed for ease in manufacture.

The grid thus efficiently separates a region of intense field strength from a region having no or substantially no field present therein, while focussing the electrons that pass therethrough. It is also significant that the component of electric field parallel to the slats **20** helps to speed electrons toward their destination, member **23**, as they are traveling therethrough. Guard structures (focussing means) which extend upward from the grid in region **25** may be mounted adjacent thereto as described in the copending application to impart a slight convergence to the field in region **25** between the grid and the detector **23** so that electrons emerging from between any of the slats are focussed toward the center of the detector or toward any other point desired.

An alternative configuration useful for other purposes is illustrated in FIGURE 3 and consists of a cylindrical array of long, electrically conductive planar slats **30**, arranged radially, so that their planes, if extended, would intersect in a common axis **32**. An electric field-free interior region **34** is established, while at the same time a strong outward field is maintained in exterior region **36** between the outer parts of the array and a coaxial, cylindrical, electrically conductive magnetic shield **38** which encloses the array. The spacing between adjacent slats is sufficiently small to prevent electric field penetration into region **34**. This radial configuration is useful with the spectrometer previously mentioned as a drift tube element wherein properly directed electrons pass longitudinally through field-free region **34** and mis-directed electrons migrate to the shield, that is, the radial array of slats **30** extends parallel to and coaxial with the desired electron drift path.

A second application of a radial configuration of planar slats is in investigations of the angular distribution of slow scattered or secondary particles which must subsequently pass through an electric field region before they can be detected. For example, electrons emitted from suitable surfaces which are heated, bombarded with fast particles, illuminated with radiation of short wavelength, or which contain a radioactive material, may scatter in many directions. Furthermore, a beam of electrons passing through a gas may scatter as described in the aforementioned copending application. The directions in which scattered electrons proceed from their points of origin is often of scientific or technological interest. In the case wherein the points of origin of the electrons lie within a field-free drift region or volume **34**, such region is partially or completely (depending upon the surface of electron emission and other considerations) surrounded by an array (plurality) of radial slat grid configurations similar to that of FIGURE 3, or comprising concentric conical members, each grid configuration comprising a pair of adjacent slat grids (or greater number of adjacent slat grids, depending upon the angular resolution desired) being maintained at an electric potential of appropriate magnitude relative to a corresponding suitable detector associated therewith. The angular distribution of emissions of the electrons is then determined by the relative response of the detectors which are positioned in the region exterior of the slat grids.

It is apparent from the foregoing that my invention attains the objectives set forth. Apparatus embodying my invention is sturdy in construction and well adapted for use in conjunction with the study of the properties of electrons. The grid effectively separates fields of differing intensity and provides a focussing action without undesirably interfering with the flight of electrons passing therethrough.

While specific embodiments of my invention have been described, the invention is not limited thereto, since many modifications may be made by one skilled in the art and the appended claims are intended to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

**1.** In an apparatus for measuring the angular distribution of electrons emitted from a body, surface, and the like, in a substantially electric field-free region,

a plurality of radial equipotential surface configurations, each configuration comprising at least one pair of spaced apart adjacent surfaces constructed of electrically conductive material which if extended radially inward would intersect in a region maintained substantially electric field-free and which is adapted to contain an electron emissive body, the region radially outward from said surfaces maintained at a higher electric field intensity wherein electron detectors are adapted to be associated with corresponding configurations of the adjacent surfaces to thereby measure the quantity of electrons emitted from the electron emissive body in the directions of the detectors,

said configurations of adjacent surfaces disposed in an array about the electron emissive body whereby the relative response of all the detectors associated with said configurations of adjacent surfaces determines the angular distribution of electron emission.

**2.** In a drift tube element wherein electrons pass through an electric field-free region,

a cylindrical array of relatively long, electrically conductive, planar slats arranged radially around a substantially electric field-free interior region in spaced apart relationship, said slats which if extended radially inward would be intersecting along a common axis in the field-free region, and

a cylindrical, electrically conductive, magnetic shield positioned around said cylindrical array in spaced apart relationship and coaxial therewith, the exterior region between said cylindrical array of planar slats and said shield maintained in a relatively strong electric field whereby electrons travelling in predetermined paths continue a passage longitudinally through the field-free region and improperly directed electrons migrate to said shield.

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WILLIAM F. LINDQUIST, Primary Examiner