

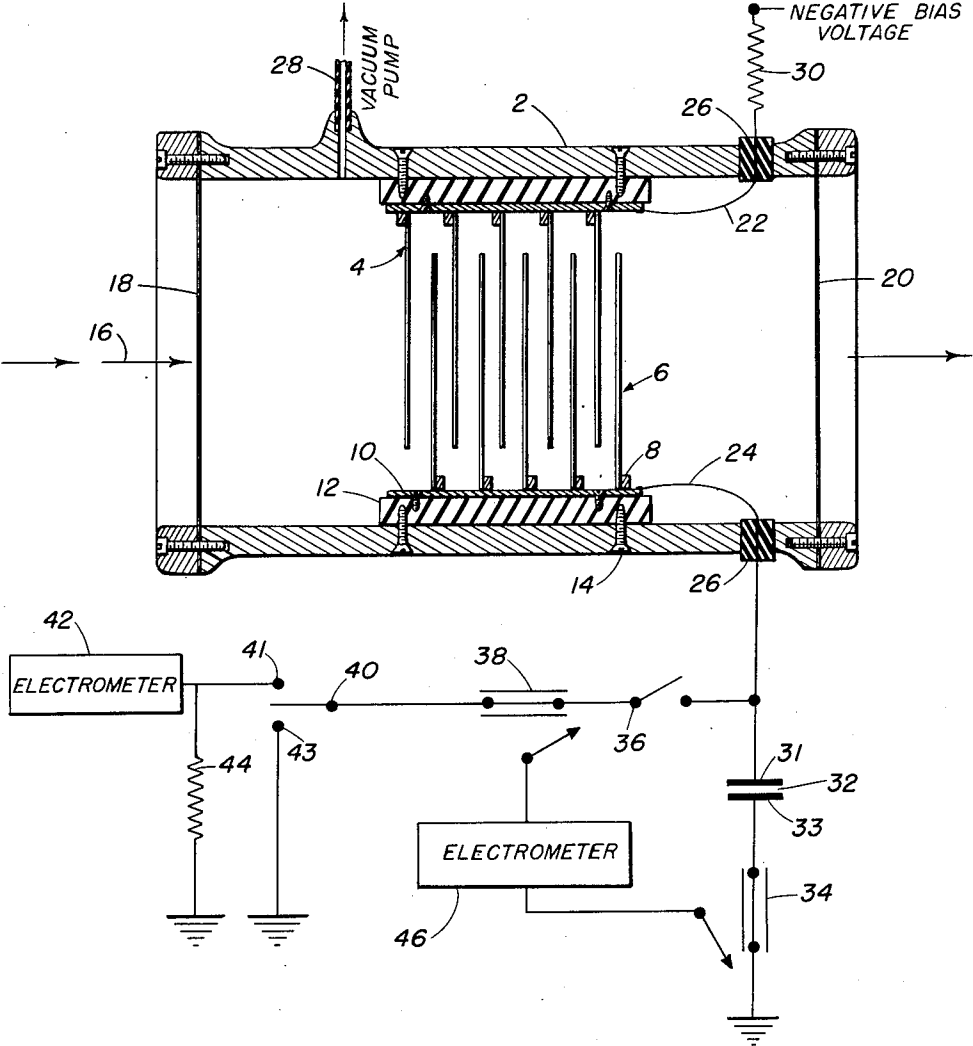
Nov. 26, 1957

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2,814,730

SECONDARY EMISSION MONITOR

Filed June 22, 1955



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2,814,730

SECONDARY EMISSION MONITOR

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Application June 22, 1955, Serial No. 517,402

4 Claims. (Cl. 250—83)

This invention relates to a high-energy beam monitor and more particularly, to a monitor for high-energy beams of charged particles utilizing the phenomenon of secondary emission.

By beam monitor is meant a device which reads, or from the reading of which can be calculated, the total number of charged particles which have flowed through a particle accelerator during any given experimental run of the accelerator. Prior art beam monitors usually use an ionization chamber but suffer from the defect that above a certain beam current density the charge collected is no longer a linear function of the flux of primary particles and the chamber is said to saturate. A principal object of the present invention, therefore, is to provide a beam monitor which is free of saturation up to relatively high peak current densities and which is independent of the primary beam energy over a relatively wide range.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein the single figure represents more or less schematically a beam-monitoring arrangement using a preferred embodiment of the invention with the secondary electron monitor per se in longitudinal cross section.

Essentially, the invention comprises a secondary electron monitor wherein the primary beam to be monitored passes through a set of foils alternately phased in voltage and the current produced by secondary electrons ejected by the passage of the beam is collected onto one of the two groups of foils comprising the set and measured. The particular size, shape, materials of construction, and electrical hook-up are subject to the greatest variation within the scope of the foregoing summary of the invention and therefore the illustrated embodiment is shown only schematically.

Reference is now made to the drawing wherein the numeral 2 represents a container enclosing two groups of foils 4 and 6. The foils are juxtaposed face to face and those of one group are arranged interdigitally or interleaved relative to the other group. The foils can be mounted in any suitable manner but one simple way is to cement each foil to an open frame, part of which is shown in cross section at 8, and then attach the frames, as by soldering, to a metal plate 10. Each foil assembly is then mounted on an insulator 12, which in turn is fastened by any suitable means, such as screws 14, to the container 2. In a typical model, thin aluminum foil (1.71 mg./cm.²) was used for the foils with brass frames and brass plates mounted on polystyrene insulators. However, any suitable materials can be used, the foil being desirably any metal which can be formed into thin sheets, preferably chosen from among the light elements to minimize multiple scattering which would undesirably spread the beam of primary particles. Since the container 2 must be maintained at a vacuum of at

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least about 10^{-4} mm. of mercury (and preferably a pressure less than 10^{-5} mm. Hg), all connections piercing the walls of the container must be vacuum-tight. This means, for example, that the screws 14 are preferably sealed with some type of sealing compound. The walls of the chamber through which the particle beam 16 passes must be made of some material which is substantially transparent to the beam and therefore will not undesirably scatter it or obstruct it. Windows 18 and 20 of "Mylar" or perhaps 3 mils to 6 mils in thickness have been found quite satisfactory since they are inexpensive and strong. Electrical conductors 22 and 24 connected respectively to foil group 4 and foil group 6 are led through any suitable vacuum-tight fittings 26 to the exterior of the container 2. The chamber containing the foils is maintained at the aforementioned required vacuum either by sealing it off completely after pumping and baking, if the insulators and other materials are of a type that can withstand the required baking, or by maintaining constant pumping through any suitable conduit 28.

The secondary electron monitor thus constructed can be connected in any suitable manner to perform its function. Means are provided for maintaining a difference of potential between the two sets of foils so that secondary electrons produced by the passage of the primary beam through the foils are collected and eventually, in effect, counted. A typical and convenient arrangement is to apply a negative bias voltage through resistor 30 to foil assembly 4. The resistor 30 serves as a protective device to limit the flow of current through the device and avoid burning up the foils if the vacuum should be lost.

Foil group 6 is connected to one plate 31 of a condenser 32, the other plate 33 of which, through a connector 34, can be connected to a common return shown, for example, as ground. Through a switch 36, the connector 38, and another switch 40, the plate 31 of condenser 32 can be connected alternatively to ground or to an instrument for measuring potential which is designated as an electrometer 42. This term is used to indicate generically any very sensitive, extremely high-impedance voltmeter which measures potential by what amounts to a null method.

Operation

It has been found that for a relatively wide range of primary electron energy tested, the number of secondary electrons emitted per primary electron passing through a foil is substantially constant. The operation of the device will become apparent from this relation. With the bias voltage connected as shown in the drawing, the collector set of foils 6 attracts the secondary electrons emitted from the emitter set of foils 4 by virtue of the passage of the primary beam 16. Any suitable magnitude of bias voltage can obviously be used. Typical trials have successfully used 300 volts to 2 kv. with 1 kv. as a convenient choice. The electrons attracted by the collector set 6 are collected on the condenser 32. When using the invention to facilitate the tune-up of a particle accelerator, for example, the switch 36 is closed and the switch 40 is thrown into connection with terminal 41 to connect the collector foils to the electrometer. The secondary electrons then flow through a relatively high impedance such as the resistor 44, which has high value (perhaps 72 megohms), to ground and the voltage indicated by the electrometer is a measure of the beam current in the primary beam. Thus the electrometer monitors the beam current.

When it is desired to obtain the total number of particles which have passed down the primary beam during a given experimental run, that is, when it is desired to integrate the beam, the switch 40 is thrown into contact with terminal 43 to ground the collector foils and then switch 36 is opened. As the experimental run progresses, the secondary electrons collect on the condenser 32. At the

end of the run, an electrometer 46 is connected between the connectors 34 and 38. This electrometer is shown in the drawing as not permanently connected inasmuch as in a practical situation it would be extremely difficult to provide adequate shielding of the cables leading from a secondary electron monitor located in the target area to such an electrometer remotely located at a control panel because the radiation flux from the accelerator in the target area would cause polarization of the coaxial cables which would be used. Hence the simple solution is to have the electrometer 46 as a portable device which is carried to the secondary electron monitor in the target area at the end of a run. The switch 36 is then closed and the potential across the condenser 32 is measured. Since the capacity of the condenser 32 is accurately known, the charge on it can be readily computed and from this, the charge on an electron also being known, the total number of secondary electrons collected on the condenser can be computed. From a theoretical computation and/or calibrating determination of the yield of secondary electrons per primary for any particular foil, the total number of primary electrons can thereafter be simply computed. A check on this secondary electron monitor can be carried out with a Faraday cup monitor. With a particular model of the invention using aluminum foils to monitor a linear electron accelerator, the invention was tested over a conveniently-operated primary electron energy range of 111 to 235 m. e. v. and found to be independent of the energy. This model gave no indication of saturation within the beam current densities tested which, in this case, happened to range up to 16 ma./cm.²

Although in the illustrated schematic embodiment the foils are located in a separate container which can be placed in the path of a particle beam emanating from an accelerator, either being interposed between the accelerator and the target or, if the target is transparent to the beam, being behind the target, the invention is equally adapted to be used directly within the accelerator itself. In this case, of course, no windows 18, 20 are necessary since the accelerator is itself maintained at the proper vacuum.

The size, shape, orientation and number of foils used in the present invention are subject to wide variation within the scope of the invention. The foils need only be large enough to span the cross-sectional area of the beam being monitored. The collector foils, serving the purpose of attracting electrons from the emitter foils, need not then even intercept the beam. That is, the collector foils could be made with an opening through their central region through which the beam can pass, which would reduce the scattering and spreading of the beam to some extent. The foils obviously can be of any shape—rectangular, circular, or other, so long as the emitter foils are of sufficient area to intercept the beam. Although the foils are illustrated as being parallel, they need not necessarily be so as long as they are so oriented so that the beam passes transversely through them. The number of foils used can vary and in experimental models arrangements have been found satisfactory using a total number of from 3 to 20 foils. The advantage of using a larger number of foils is to increase the ease and accuracy of counting since the total number of secondary electrons is greater, some being omitted from each emitter foil. An excessive number of foils would possibly cause some unwarranted scattering of the beam.

Obviously many modifications and variations of the

present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A device of the character described comprising a first plurality of thin metallic foils juxtaposed face to face in spaced relation to one another and electrically connected together; a second similar plurality of thin metallic foils juxtaposed in face to face spaced relation to one another and electrically connected together; means mounting said two pluralities of foils in interdigital relation; said foils being made of a material having a low atomic number; means for applying a D. C. voltage between said two sets of foils; a container having opposite ends provided with material substantially transparent to a high-energy electron beam, said pluralities of foils being mounted within said container and so oriented relative to said ends of said container that an electron beam entering one end of said container passes transversely through said foils and thence out the opposite end of said container, the interior of said container being maintained at a vacuum of at least about 10^{-4} mm. of Hg; the region between adjacent foils being substantially free of any matter which can obstruct the passage of an electron beam; a condenser; means connecting the relatively positive set of said foils to said condenser whereby secondary electrons emitted from said foils upon the passage of an electron beam through said container are collected by said condenser.

2. A device of the character described comprising a plurality of thin metallic foils juxtaposed face to face in spaced relation; the region between adjacent foils being substantially free of any matter which can obstruct the passage of an electron beam; means for electrically connecting together alternate foils to form two groups; said foils being made of a material having a low atomic number; means whereby a source of voltage can be connected to said groups of foils to establish a potential difference between said groups; and means for maintaining said foils in a vacuum of at least about 10^{-4} mm. of Hg.

3. The device of claim 2 further including a voltage source connected to maintain a difference of potential between said foil groups whereby the relatively positive of said groups constitutes a collector group which attracts secondary electrons produced by the passage of a particle beam through said foils; a condenser connected to said relatively positive group to collect said secondary electrons; and means for measuring the voltage across said condenser.

4. The device of claim 2 further including a voltage source connected to maintain a difference of potential between said foil groups whereby the relatively positive of said groups attracts secondary electrons produced by the passage of a particle beam through said foils; an impedance connected in such a manner that secondary electrons collected by said collector group of foils can flow off said collector group through said impedance; and means for measuring the voltage drop across said impedance occasioned by the flow of secondary electrons therethrough.

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