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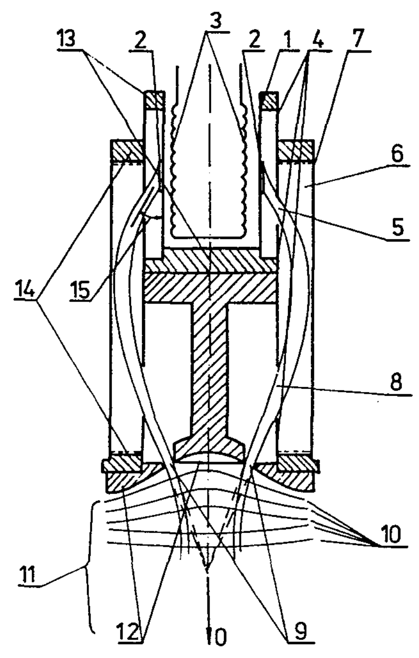
(54) **Method and electron gun for generating an electron beam, particularly of high current density at the surface of its utilisation.**

(57) The electrons emitted from a cylindrical cathode (1) by the method as per this present invention are formed in the electric field at the cathode into a beam with divergent paths being on the surface of coaxial cones the apex angles whereof are contained in an interval varying within the limits of 0-0.5 radian around their central angle (15) of 0.1-1.5 radians. Next, electrons with a narrow energy interval are separated from the beam by means of a cylindrical mirror analyser (4, 7) after curving the electron paths therein and selecting them with the application of slits (8, 9). These electrons are then converged in a set of electron lenses (117).

The electron gun has a cylindrical cathode (1) having a part of the surface in the form of a 0.01-10 mm wide ring coated with emission paste (2). Electrodes (4, 7) of the cylindrical narrow analyser are mounted around the cathode (1). An inlet slit (5) of the internal electrode (4) is shifted horizontally in relation to the active cathode surface coated with emission paste (2) so that the angle between the electron beam in the region of that slit (5) and the axis (0) of the system is contained within an interval of 0-0.5 radian around their central angle (15) of 0.1-1.5 radians.

The electron gun comprises an electrode (12) placed between the analyser (4, 7) and the set of electron lenses (11) and co-forming equipotential lines (10) with a coaxial circular ring-shaped slit (9).



EP 0 138 199 A2

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METHOD AND ELECTRON GUN FOR GENERATING AN ELECTRON BEAM, PARTICULARLY OF HIGH CURRENT DENSITY AT THE SURFACE OF ITS UTILISATION

The present invention relates to a method and an apparatus for generating an electron beam, particularly of high current density at the surface of its utilisation, particularly a beam with modulated current intensity as well as to the application therof in electron-beam instruments, particularly in colour and monochrome picture and oscilloscope and monitor tubes.

A known method for generating an electron beam with modulated intensity and high current density at the surface and for its utilisation involves causing an emission from a cathode, preferably by heating the latter, with a possibly high beam density at the emitting surface, the formation of an electric field having an intensity being modulated close to the cathode and determining that part of the electron beam emitted which is returned to the cathode, the initial acceleration and generation of a beam of the remaining part of the said current of higher velocities, and obtaining a distribution electric, or electric and magnetic fields such that it forms a system of electron lenses and thus causes the electron beam to be accelerated to the necessary final velocity and images the surface, image or cross-over of the cathode on the surface of utilising the beam, with the linear magnification remaining as low as possible.

The above method is used in one of the latest and most perfect electron gun designs intended particularly for being used in picture, oscilloscope and monitor tubes (cf. US-A-3 740 607).

In the known electron guns adapted for being used in picture, oscilloscope and monitor tubes, the increase in the beam current density at the surface of its utilisation is mainly restricted by the effects resulting from the Maxwell distribution of the electrons emitted from the cathode and forming the said beam. The other restrictions co-determining the possible generation of a high-density beam, such as electron diffraction and spatial beam charge effect, are of considerably lower or simply negligible significance in the class of electron guns under dicussion.

The restrictions resulting from electron-optical observations can be minimalised by the proper design of the electron-optical systems of the electron guns under discussion.

In accordance with the formula derived by Langmuir and defining the relation which results from the Maxwell electron velocity distribution of the beam and

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relates the maximum beam current density that can be obtained at the surface of the beam utilisation, i.e. at the target or screen, to the known parameters of the electron gun and the electron beams generated in them, the said maximum beam current density can be increased, with the symmetry of rotation of the electron gun and a low linear magnification of the system of its imaging lenses assumed, by increasing the density of the current taken from the cathode, increasing the voltage of the target or screen in relation to the cathode, decreasing the cathode temperature and/or increasing the half angle of the beam cone.

Some of the above requirements contradict each other, e.g. that for the simultaneous increase in cathode current and decrease in temperature. Each of these requirements can thus be implemented within certain circuits only, resulting from the contemporaneous technology and engineering.

In connection with the above it is worth stressing that certain of the said requirements can cause essential trouble in the application and correct operation of an instrument or an electron gun, e.g. a voltage increase by even 10 kV presents hazards of electrical breakdowns and makes one to provide protections against X-rays. An increase in that half angle leads in turn to an excessive increase in the aberration of electron-optical imaging and deflecting systems.

An approach to the peak value of current density is not easy, e.g. in the case of crossover electron guns this involves the major part of the current taken from cathode being eliminated by the restricting holes located in imaging lenses and, thus, the beam peak current being restricted and the power required for the generation of an electron beam of high current density at the surface of its utilisation being increased.

The situation in this respect is more favourable for laminar flow electron guns where the majority of the current taken from the cathode reaches the target or screen.

The beam current density can also be increased at the target by the application of a system of electron, electric or magnetic lenses of sufficiently low linear magnification which is accompanied by an increase in the ratio of the object - object focus distance of the lens system to the image focus - imaging of the lens system. With that second distance predetermined, as is the case with, among other things, picture, oscilloscope and monitor tubes, this leads to an increase in the length of the electron gun and, thus, of the entire instrument unless use is made in that imaging of the cathode image located far beyond the real cathode surface, as is the case with laminar flow beams.

That method is also presented in the US-A-3 740 607. Thus, an increase in the beam current density at the target would usually involve an inpairment in the other parameters of an cathode ray tube and, thus, a compromise is required.

An electron gun is known from US-A-3 740 607 in which a high beam current density is obtained by the method described, with its other qualities retained.

The above mentioned electron gun comprises an indirectly heated cup-shaped cathode having a resistance heater protrusion disposed on its bottom. Emission paste is applied to the face of that protrusion. The control electrode has a hole and surrounds the said cathode protrusion so that its face making an angle of 0-45° with a surface perpendicular to the axis is close to the emitting surface of the electrode and is an essential continuation of that cathode surface. This electrode is a modulator.

The anode of the electron gun under discussion is axially moved away from the cathode and is made in the form of a cylinder with its turned-over edge directed towards the cathode. This edge has a hole with its diameter being larger than that of the cathode protrusion, and the surface of that edge is one tapering towards the surface perpendicular to the electron gun axis at an angle of 0-45°. The above moving of the anode away from the cathode, theangles of inclination of the face of the control electrode and the anode edge in relation to the surface perpendicular to the electron gun axis, and the voltage applied to the control electrode and anode are all matched so that the electric field thus obtained should be directed normally to the entire emitting surface of the cathode and form a diverging electron lens far from the cathode.

There are two additional cylindrical electrodes placed behind the anode having its potentials higher than that of the anode and ensuring the formation of two accelerating converging electron lenses. If required,use is still made of a magnetic system consisting of a coil placed outside of the housing of the instrument incorporating the electron gun for forming a magnetic electron lens.

The electrons emitted from the active surface of the cathode with their energies being sufficient to overcome the minimum cathode potential are markedly accelerated and move along almost parallel paths to provide for laminar flow. Close to the hole in the turned-over edge of the anode these paths diverge to form the virtual image of the cathode for behind the emitting part of the cathode.

The above virtual cathode image is an object for the system of converging lenses and, thanks to its great distance from them, it enables a representation of very low magnification to be obtained at the surface of utilisation of the band, i.e. on the target or screen. Such an implementation allows one to essentially approach to the limiting current a density expressed by the Langmuir without considerable current losses in electron guns, since A. Silzar and D.J. Bates reached 30 % of the said theoretically possible maximum current density in an embodiment.

Such a design also allows one to essentially restrict the voltage setting of the modular, indispensable for changing the beam current from very small to maximum values. The cut-off voltage of the electron gun of this type continues to be of the order of a dozen or so to a score or so of volts.

Though essentially lower than that of the crossover electron guns, the degradation of resolution continues to be a score or so per cent as current increases.

According to the present invention, from the beam emitted from the cathode are separated the electrons of divergent paths being on the side surfaces of coaxial cones, with the apex angles contained within 0-0.5 radian about their central angle and 0.5-1.5 radians and, before focussing them in the set of electron lenses, electrons with a narrow energy interval of 0-1 eV are separated from them, preferably bending their paths in a circular symmetrical energy analyser.

In the electron gun as per the invention the forming electrodes form a circular symmetrical energy analyser whose inlet slit is shifted axially in relation to the active surface of the cathode so that the angle between the electron beam within the region of that gap and the axis of the system varies within 0-0.5 radian about their central angle of 0.1-1.5 radians. The cathode of the electron gun can also be shaped as a cylinder whose part of the surface in the form of a ring, 0.01-10 mm wide, is coated with an emission paste. The electron gun can also be provided between the analyser and the set of lenses with an electrode which co-forms equipotential lines with a narrow coaxial ring gap. In another embodiment, that gap can be circular, eliminating electrons of higher azimuthal velocities and impinging at incorrect angles.

In both the electron gun embodiments, the electron beams formed in them are sharply restricted with respect to energy and direction of motion.

In this case, the possibility of designing an almost optional shape of that end electrode provides the basis for essentially restricting the length of the set of electron lenses and, consequently, for shortening the entire instrument, e.g. the picture tube neck.

As per this present invention the Langmuir requirement for the maximum current density which can be obtained in the region of its application, is not longer valid, since the electrons do not show the Maxwell distribution. This enables markedly higher current densities to be obtained on the target or screen if the set of electron lenses has been correctly designed. The invention permits the position of the electron gun control characteristics to be regulated, which is related to the possible selection of the mean energy of the flux of the electrons entering the region under analysis. This energy can be preferably selected by initially accelerating the electrons emitted from the cathode. This is of particular importance for ensuring the comenticity of controlling three electron guns in a colour picture tube.
In addition to the above, the electron gun as per this present invention shows a low voltage of the electrode modulating the beam current intensity of almost ideally exponential beam current modulation characteristics and, also, small changes in the beam size at the surface of its utilisation with current intensity changing. The electron gun as per this present invention makes the cathode operating conditions independent of the instantaneous value of the beam current intensity. The cathode is also protected from its harmful bombardment with the positive ions formed in the region of

the acceleration and drift of the beam.

The invention is explained in more detail by way of an example shown in the drawings wherein

Fig. 1 presents an electron gun in axial section with the electrode placed between the analyser and the set of lenses in the circular slit and

Fig. 2 shows an electron gun with a ring slit in that electrode.

A cathode 1 indirectly heated by a heater 3 has the form of a cylinder. A part of the surface of the heater 3 has the form of a 1 mm wide ring coated with emission paste 2 being the emissively active part of the cathode 1.

Electrodes 4 and 7 forming the electron beam and having their velocity distribution sharply restricted, both as to value and direction, have the form of coaxial cylinders. They form a circular symmetrical energy analyser whose inlet slit 5 is axially shifted in relation to the active surface of the cathode 1 coated with the emission paste 2 so that the electrons enter the zone 6 of analysis between electrodes 4 and 7, the angles to the axis of the system being contained in a narrow interval of 0.6-0.8 radian.

The cylinders of electrodes 4 and 7, with the end of external electrode 7 shifted close to the slit 5, are mounted around the side surface of the cylinder of the cathode 1 being coaxial thereto. This partial mounting of the cylinder of the external electrode 7 around the cylinder of the internal electrode 4 and that of the cathode 1 is preferred in order to minimise the capacity of the electrode 7 of the modulator in relation to the remaining electrodes of the system.

In the zone 6 of analysis, the electron paths are curved depending on the initial energy of the electrons and the angle between the vectors of their velocities and the axis 0 of the system and on the voltage between internal electrode 4 and external electrode 7 negatively polarised towards the former and being a modulator. That voltage is of the order of some to a dozen or so of volts.

Thus, outlet slit 8 is reached only by the electrons with energies and directions of movement contained within a narrow interval of 0.1-0.2 radian around the central angle 15 of 0.7 radian, and the current flowing through the slits 8 can easily be controlled by changing the voltage between the electrodes 4 and 7 of the analyser. Consequently, the electron beam leaving the analyser is sharply restricted in energy and angle.

The electrons move on almost straight lines until they reach the slit 9 of the electrode 12 co-shaping equipotential lines 10. After leaving the slit 9 the electrons are accelerated, formed and focused by means of a set of electron lenses 11 formed by an electric field with equipotential lines 10. These lenses are made by the classical method using a set of cylindrical electrodes and magnetic coils.

The electron gun electrodes are connected with ceramic rings and discs 13 and 14. Rings 14 are coated on one side with thin metallic or resistance layers, as is usually done, to prevent the field distribution to be disturbed in zone 6 of analysis.

The application of the coaxial circular slit 9 with a radius of tens of micrometers, as shown in Fig. 1, an electrode 12 enables the crossover version of the electron gun to be obtained and allows the effect of the azimuthal velocity of the electrons to be eliminated thanks to only electrons capable of sufficiently nearing the axis of symmetry of system 0 being separated from the beam.

In the design in question, greater role is played by the spatial charge.

The application of the narrow ring slit 9 in the electrode 12, as shown in Fig. 2, enables the laminar flow version of the electron gun to be obtained. The effect of the spatial charge is then decreased with the beam current and electron energy remaining the same.

The method as per the invention is thus used for separating electrons of divergent paths being on the side surfaces of the cones with apex angles contained in a narrow interval of the order of 0.1-0.2 radian around a central angle 15 of 0.7 radian from the beam emitted from the cathode 1 by means of an electric field regulated with voltage between electrode 4 and cathode 1 and thanks to the active ring-shaped surface of the cathode 1 in relation to the slit 5 of the cylindrical energy analyser through which passes the beam at its further run.

Next, even before markedly accelerating and focussing the said electrons in the set of electron lenses 11 they are subjected to an analysis of energy in order to separate from them the electrons with a narrow interval of energy by curving their paths in the cylindrical mirror energy analyser and selecting the electrons of required energies with slits 8 and 9. The electron beam leaving the slit 9 has thus a sharply restricted velocity distribution, both as with respect to energy and direction.

The said actions take place at a low level of energy so that they should not involve considerable losses of energy, an essential heating of the electrodes and diaphragms being bombarded, or troublesome secondary emission. The beam current intensity, is regulated by selecting the mean energy of the electrons transmitted by the said analyser of the energy generated in a preferred cylindrical mirror analyser by changing the voltage of electrode 7, being a modulator and moved far away from the cathode and, thus, practically not effecting the operating conditions of the emissively active part 2 of its surface, which leads to extending the life of cathode 1.

In addition to the above, cathode 1 is separated from the zone of acceleration by the energy analyser and, thus, protected in an essential manner against being bombarded with the positive ions of residual gases, which essentially extends its life.

Due to a low level of energy of the electrons under analysis, the voltages applied between electrodes 4 and 7 for the purpose of regulating the current intensity are low enough that the cut-off voltage can be of the order of single volts, which prefers the design as per this present invention for use in conjuction with transistor systems.

The beam current modulation characteristic is almost ideally exponential and repetitive due to the Maxwell velocity distribution of the electrons emitted from the cathode, which prefers the method as per this present invention in many applications, e.g. the picture tubes employed in TV sets. This characteristic can besides be shifted by changing the voltage of cathode 1 in relation to electrode 4.

A change of the beam current by the method as per this present invention causes a slight change only, not exceeding 1-2 eV, in the kinetic energy of the electrons leaving slit 9 in electrode 12 and, thus, a change in the beam size at the surface of its utilisation is determined first of all by chromatic observation and by the spatial charge of the beam. Consequently, changes in the cross sizes of the beam accompanied by an increase in current intensity are essentially smaller than those of the known electron guns.

Claims

1. A method for generating an electron beam, particularly of high current density at the surface of its utilisation and modulated current intensity, by emitting electrons from a cathode (1) whereby electrons are accelerated, converged and focused in a set of electron lenses (11) after the initial formation of the beam, characterized in that the beam emitted from the cathode (1) is stripped off the electrons with divergent paths being on the side surfaces of coaxial cones whose apex angles are contained in an interval, the magnitude whereof ranges within the limits of 0-0.5 radian around their central angle 15 of 0.1-1.5 radians and electrons of a narrow energy interval of 0-1 eV are separated therefrom by preferably curving their paths in a circular symmetrical energy analyser.

2. An electron gun generating a beam, particularly of high current density at the surface of its utilisation and comprising a cathode (1), beam forming electrodes (4, 7) and a set of electron lenses (11) converging that beam, characterized in that the electrodes (4, 7) forming the electron beam form

a circular symmetrical energy analyser, an inlet slit (5) being shifted axially in relation to the active surface of cathode (1) so that the angle between the electron beam in the region of that slit (5) and the axis 0 of the system is contained within an interval of 0-0.5 radian around their central angle (15) contained within an interval of 0.1-1.5 radians.

3. An electron gun as per claim 2, c h a r a c t e r i z e d in that the cathode (1) is a cylinder, a part of the surface thereof having the form of a 0.01-10 mm wide ring coated with emission paste (2).

4. An electron gun as per claim 2, c h a r a c t e r i z e d in that it comprises an electrode (12) placed between the analyser (4, 7) and the set of electron lenses (11) and co-forming equipotential lines (10) with a coaxial circular or ring-shaped slit (9).

5. An electron gun as per claim 3 and 4, c h a r a c t e r i z e d in that the said part of the surface of the cylinder comprises an electrode (12) place between the analyser and the set of electron lenses (11) and co-forming equipotential lines (10) with the coaxial circular or ring-shaped slit (9).

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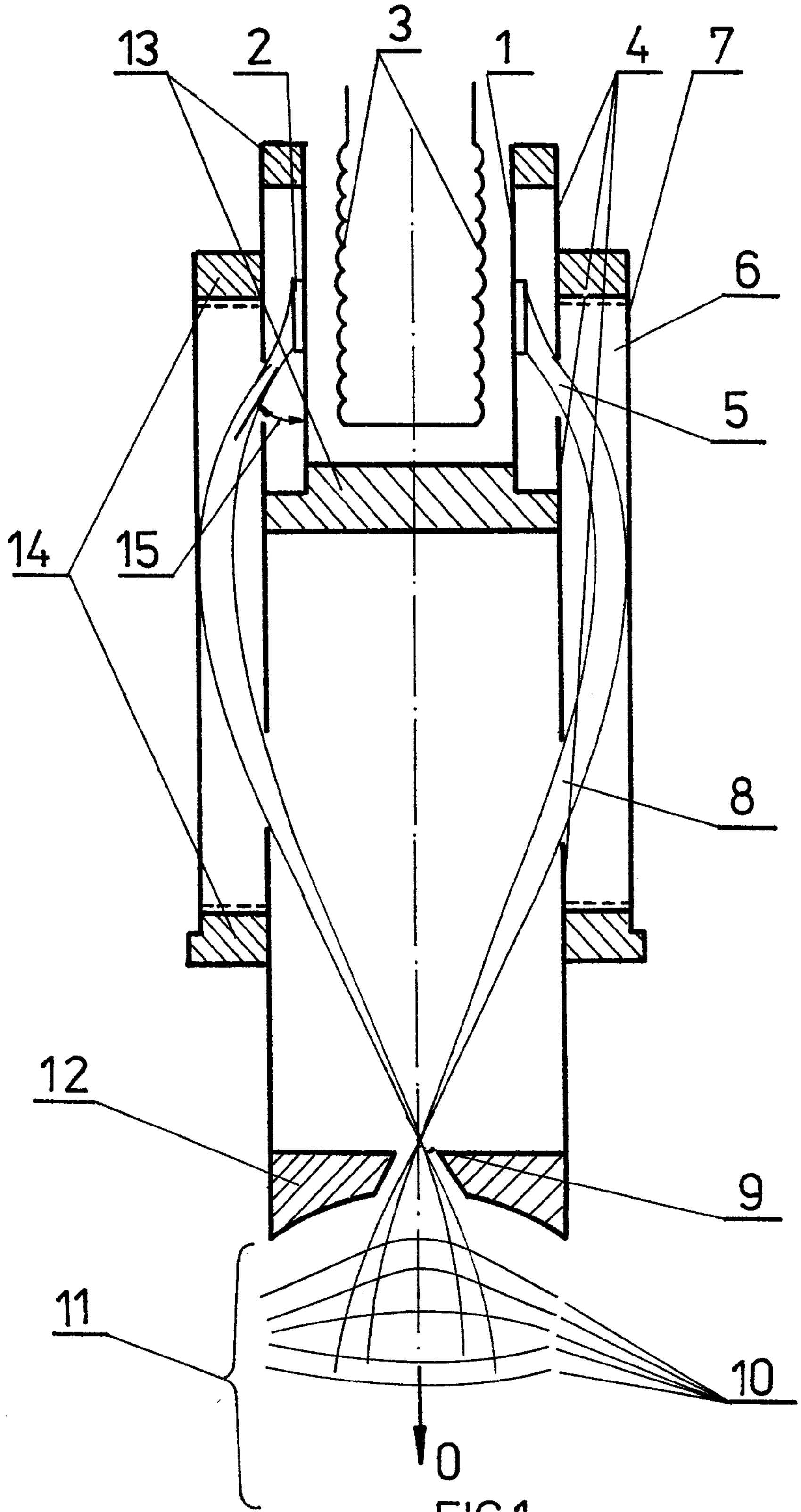

FIG.1

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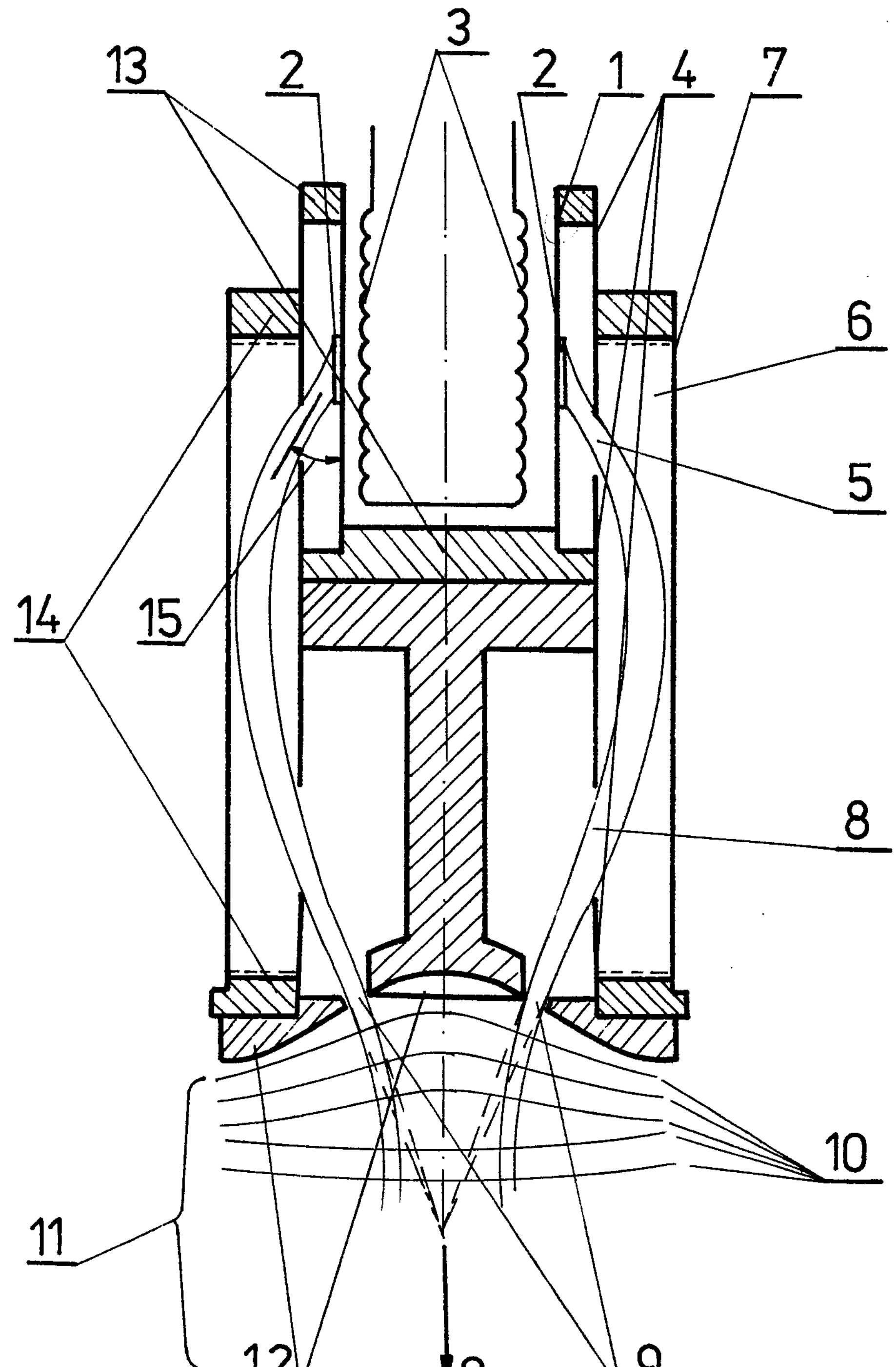

FIG.2