Dec. 30, 1952 O. WOLFF 2,624,022

DEVICE FOR REGULATING THE FOCAL LENGTH OF MAGNETOSTATIC POLE SHOE LENSES

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Fig. 1a.

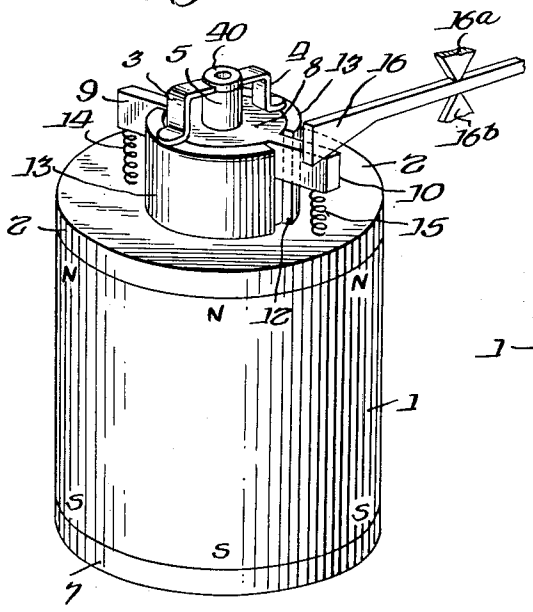


Fig. 1b.

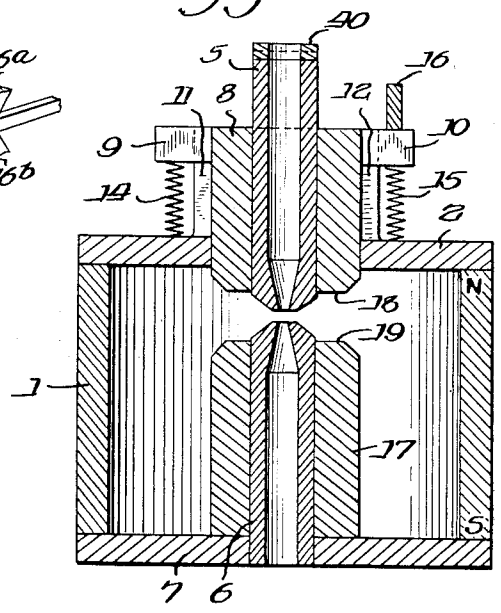


Fig. 2a.

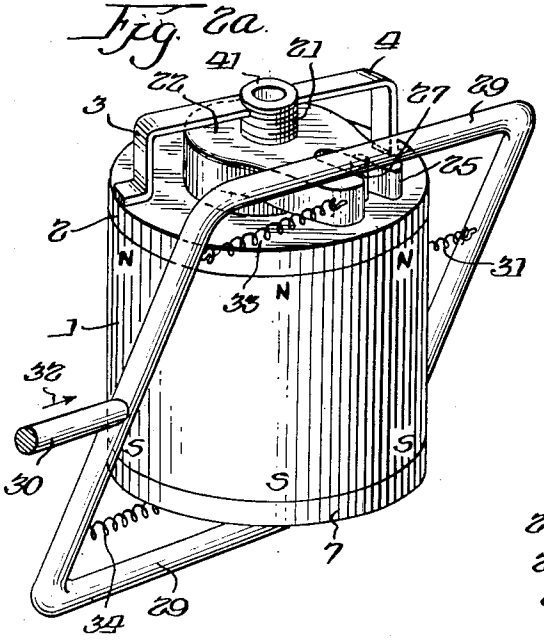
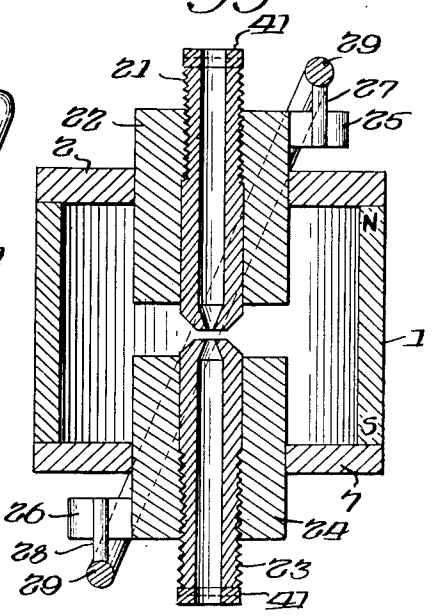


Fig. 2b.



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DEVICE FOR REGULATING THE FOCAL LENGTH OF MAGNETOSTATIC POLE SHOE LENSES

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11 Claims. (Cl. 313—84)

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This invention is concerned with a device for adjusting or regulating the focal length of magnetostatic pole shoe lenses.

Magnetostatic lenses are used in apparatus for projecting electrons, and especially in electron microscopes. If the focal length of such lenses is to be regulated, they must be provided with mechanical means for affecting the magnetic flux. Known apparatus of this kind are usually so constructed that regulation of the focal length is possible only within certain limits and in such a manner that they permit only diminution thereof.

The object of the invention is to construct the regulating or adjusting means so that the refractive power of the lens is in one terminal position of the adjusting means nearly at zero, thereby practically disconnecting the lens. This is of particular importance, e. g., in the case of an electron microscope which is constructed for selectively making either ultramicroscopic exposures or electron-deflection exposures. It may under certain circumstances be essential, in such apparatus, to disconnect the lens effect of the lenses remaining in the beam path.

This object is realized by the provision of a flux-regulating member which is associated with the fixedly disposed pole shoes, such regulating member surrounding the pole shoes concentrically and being axially adjustable relative thereto. The pole shoe system of such a lens therefore remains stationary during the regulation, which is favorable for the formation of the field in the effective lens range, while the regulation is effected by the displacement of the regulating member which surrounds the pole shoes in the manner of a tubular jacket.

The device is, in accordance with the invention, preferably so constructed that the flux-regulating member engages in one terminal position a coacting member which forms part of the magnetic circuit, thereby practically shunting the lens. The coacting member may be an element which is fixedly connected with a pole shoe, or it may be in the form of an element which is axially adjustable just like the flux-regulating member. In this latter case the two members are brought into engagement in terminal positions thereof which correspond to the shunting of the lens, the plane of engagement of these members lying in an intermediate area between the two pole shoes of the lens. Such arrangement permits retention of the symmetrical structure of the magnetostatic lens in any flux-regulating position.

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The displacement of the flux-regulating member and, if desired, also of the coacting member, may be accomplished by rectilinear motion. It is, however, also possible to carry out the axial displacement by rotation of the regulating member in the manner of a screw. A particularly simple embodiment may be obtained by choosing the pitch of the screw thread so that an approximately ninety degree rotation of the corresponding regulating member suffices to bring it from one to the other terminal position.

The actuating means for rotating the corresponding regulating member comprises a rodlike member which is journalled in the vacuum wall of the apparatus and is movable only in axial direction, and drive means operated by the rodlike member which engages the regulating member at an eccentrically disposed point thereof. Spring means are provided for holding the corresponding flux-regulating member in a normal terminal position which is preferably the position in which the lens is shunted or short-circuited.

The various objects and features of the invention will be brought out in the course of the detailed description wihch will presently be rendered with reference to the accompanying drawings. In these drawings,

Fig. 1*a* is a simplified perspective view of an embodiment of the apparatus which employs a regulating member which is axially movable in a straight-line motion;

Fig. 1*b* shows the embodiment of Fig. 1*a* in transverse sectional view; and

Figs. 2*a* and 2*b* illustrate in similar representation an embodiment having a flux-regulating member which is rotatable in the manner of a screw, to bring about its axial displacement.

The drawings show only the inner lens part of an apparatus such as an electron microscope. It is understood of course that this lens part is in vacuum tight manner disposed within an outer housing or casing, which has been omitted from the drawings to keep them simple.

Referring now to the embodiment shown in Figs. 1*a* and 1*b*, numeral 1 indicated a cylindrical pot magnet forming at the top the north pole and at the bottom the south pole for the associated magnetostatic lens. The upper pole shoe 5 is secured to the central part 40 of a bridge member having the arms 3 and 4 which are fastened to and extend from the sleeve 13, the sleeve being mounted on the lid 2. The lower pole shoe 6 is secured to the bottom member 7. Fixedly associated with this pole shoe 6 is a coacting regulating member 17. The parts 6 and 17 may be

made integral, if desired. The upper pole shoe 5 is surrounded by the flux-regulating member 8 which is axially movable relative to the pole shoe 5 inwardly and outwardly of the lid 2. The regulating member 8 carries the laterally extending arms 9 and 10 which are guided in slots 11 and 12 of the sleeve 13. Numerals 14 and 15 designate springs which hold the regulating member 8 in a desired terminal position, e. g., in its upper terminal position, as shown. The downward displacement of the member 8 is accomplished by a leverlike adjusting rod 16 which may be fulcrumed at 16a—16b. When the member 8 is displaced downwardly into its alternate terminal position, its transversely extending lower end 18 will be brought into engagement with the transversely extending upper end 19 of the coacting regulating member 17, thereby providing the desired shunt for the lens.

The adjusting lever 16 may be suitably mounted in vacuumtight manner relative to the outer wall of the apparatus and may be operated from the outside by a suitable drive so as to displace it relative to the arm 10 of the regulating member 8, its wedgelike inner end coacting with the edge of arm 10 to depress the member 8 inwardly in the manner described above. Any suitable and desired guide means may be provided for the lever 16. It is of course also possible to mount the lever 16 pivotally and to provide suitable link means extending in vacuumtight manner to the outside of the apparatus for actuation by the operator so as to rock the lever 16 for the purpose of moving the flux-regulating member 8 axially, as explained before.

The above described structure shown in Figs. 1a and 1b may easily be modified to make the coacting flux-regulating member 17 movable in a manner similar as the member 8. The two members 8 and 17 may then be displaced simultaneously so that the transversely extending surfaces 18 and 19 at the free ends thereof engage in a plane which corresponds to a central or intermediate region of the lens. It is only necessary for this purpose to mount the pole shoe 6 in a manner similar to the mounting of the pole shoe 5 and to modify the member 17 to conform substantially to the structure of the member 8. Similar drive means, including a lever such as 16, may then be employed for operating the member 17.

The actuating levers such as 16, one for the flux-regulating member 8 and one for the flux-regulating member 17 (in a structure in which both of these flux-regulating members are movable), may form the prongs of an actuating fork having a shaftlike extension which projects in vacuumtight manner to the outside for actuation by the operator.

The device shown in Figs. 2a and 2b employs a rotatable flux-regulating member and a coacting member for rotating it to bring about the axial displacement thereof. Reference numerals in these figures, which correspond to those used in the first described embodiment, indicate identical parts. The upper pole shoe 21 is, in this form of the invention, associated with a flux-regulating member 22, and a similar flux-regulating member 24 is associated with the lower pole shoe 23. The pole shoes 21 and 23 are fixedly secured, each to the central part such as 41 of a bridge member having arms 3 and 4 which are mounted on the corresponding lid and bottom members 2 and 7 of the pot-shaped magnet 1. The flux-regulating member 22 carries at its outer end a forked lateral extension forming the slot 25, and the member 24 carries at its outer end a similar forked lateral extension forming the slot 26. A frame member 29 is provided which carries drive pins 27 and 28 disposed in the slots 25 and 26, respectively. The flux-regulating members 22 and 24 are mounted on the coacting pole shoes by screw threads, as shown. Accordingly, when the frame 29 is shifted laterally of the lens structure, the pins 27 and 28 will rotate their associated flux-regulating members 22 and 24 to move these members axially for the purpose of bringing about the shunt for the lens, as described before. The pitch of the screw threads is so that an approximately ninety degree angular displacement of the members 22 and 24 suffices for moving these members from the illustrated terminal positions (Fig. 2b) in which the lens has its shortest focal length to the alternate terminal position in which it is practically short-circuited.

To bring about the adjustment, the frame 29 is provided with a drive or actuating rod 30 which which may be axially displaced by a suitable drive means in the direction of the arrow 32. The rod 30 extends in vacuumtight manner through the outer wall of the apparatus to the outside, for actuation by the operator through the medium of any desired and suitable actuating means so as to bring about the displacement as described.

This particular structure employing the frame 29 therefore makes it possible to move the flux-regulating members 22 and 24 toward and away from each other by means of a single drive or actuating rod such as the rod 30. A spring 31 is provided to hold the frame 29 in a normal position, which is preferably the position in which the flux-regulating members are in engagement for short-circuiting the lens. Actuation of the drive rod 30 in the direction of the arrow causes angular displacement of the flux-regulating members 22 and 24, and therewith axial motion thereof outwardly, therefore gradually increasing the refractive power of the lens. The spring shown at 33 holds the forked portion of the flux-regulating member 22 in engagement with the pin 25 of the frame so as to eliminate any undesired play between the pin and the forked member. A similar spring 34 is provided at the other end of the structure to coact, in a similar manner and for similar purposes, with the forked portion of the flux-regulating member 24.

It may be mentioned in conclusion, that the means for actuating the drive members, such as 16 and 30, respectively, or equivalent members, may be constructed along the lines of the drive means for certain regulating members as shown in copending application Serial No. 244,195, filed August 29, 1951.

I claim:

1. In apparatus for projecting electrons including fixedly disposed pole shoes forming a magnetostatic lens, a device for regulating the refractive power of said lens to adjust the focal length thereof, said device comprising a tubular movably mounted flux-regulating member forming part of the magnetic circuit of said lens, said movable flux-regulating member being disposed concentrically with respect to said pole shoes, and means for axially displacing said movable flux-regulating member.

2. The structure defined in claim 1, together with a coacting flux-regulating member forming part of the magnetic circuit of said lens, said movable flux-regulating member engaging said coacting flux-regulating member in one of its

terminal positions for the purpose of substantially short-circuiting said lens.

3. The structure defined in claim 1, together with a movable coacting flux-regulating member forming part of the magnetic circuit of said lens, means for axially displacing said movable coacting flux-regulating member, corresponding ends of said flux-regulating members being in identical axial terminal positions thereof in engagement in a plane which corresponds to an intermediate range of said lens, said lens being substantially short-circuited when the ends of said flux-regulating members are in engagement in said plane.

4. The structure defined in claim 1, together with actuating means for rotating said flux-regulating member to effect the axial displacement thereof.

5. The structure defined in claim 1, together with screw thread means for rotating said flux-regulating member to effect the axial displacement thereof, said screw thread means comprising a thread having a pitch to provide for displacement of said flux-regulating member from one to the other terminal position responsive to rotating it through about ninety degrees.

6. The structure defined in claim 1, together with actuating means for rotating said flux-regulating member to effect the axial displacement thereof, said actuating means comprising a rodlike axially movable member, and drive means in engagement with an eccentric point of said flux-regulating member, said drive means being operable by said rodlike member to rotate said flux-regulating member.

7. The structure defined in claim 1, together with actuating means for rotating said flux-regulating member to effect the axial displacement thereof, said actuating means comprising a rodlike axially movable member, drive means in engagement with an eccentric point of said flux-regulating member, said drive means being operable by said rodlike member to rotate said flux-regulating member, and spring means for holding said flux-regulating member in one terminal position thereof.

8. In apparatus for projecting electrons which includes fixedly disposed pole shoes forming a magnetostatic lens, a device for regulating the refractive power of said lens to adjust the focal length thereof, said device comprising a tubular flux-regulating member for each pole shoe which surrounds the associated pole shoe in the manner of a jacket, screw thread means for rotatably securing each flux-regulating member, means for rotating said flux-regulating members to effect axial displacement thereof, corresponding ends of said flux-regulating members being in identical terminal positions in engagement to substantially short-circuit said lens, said screw thread means having a pitch to provide for axial displacement of said flux-regulating members from one to the other terminal position responsive to rotation thereof through about ninety degrees.

9. The structure defined in claim 8, together with actuating means comprising a rodlike axially movable member, and drive means in engagement with eccentric points of said flux-regulating members, said drive means being operable by said rodlike member to rotate said flux-regulating members.

10. The structure defined in claim 8, together with actuating means comprising a rodlike axially movable member, drive means in engagement with eccentric points of said flux-regulating members, said drive means being operable by said rodlike member to rotate said flux-regulating members, and spring means for holding said flux-regulating members in identical normal axial terminal positions thereof.

11. The structure defined in claim 8, together with actuating means comprising a rodlike axially movable member, drive means in engagement with eccentric points of said flux-regulating members, said drive means being operable by said rodlike member to rotate said flux-regulating members, and spring means for holding said flux-regulating members in the axial terminal positions thereof in which said lens is substantially short-circuited.

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