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FOREIGN PATENTS

981,295 1/1965 Great Britain..... 250/49.5

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[54] **ADJUSTING DEVICE FOR CORPUSCULAR-BEAM
 APPARATUS**
 12 Claims, 3 Drawing Figs.

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 356/244

[51] Int. Cl..... **H01j 37/26**

[50] Field of Search..... **250/49.5 B,**
 51.5 R; 356/244; 108/28; 248/122, 178, 287

[56] **References Cited**

UNITED STATES PATENTS

2,421,696 6/1947 Hillier 250/49.5

ABSTRACT: A corpuscular-beam apparatus wherein a component, such as a diaphragm or specimen table, requires adjustment perpendicularly to the radiation axis of the apparatus. This component which requires such adjustment slidably engages a supporting surface which is normal to the radiation axis. An adjusting means, which can be actuated from the exterior of the evacuated apparatus, is provided for bringing about the required adjustment of the component. A clutch means is situated between this adjusting means and the component for transmitting movement from the adjusting means to the component only when the clutch means is in an engaged position. This clutch means can be displaced between its engaged position and a disengaged position where said clutch means prevents any transmission of movement from the adjusting means to the component.

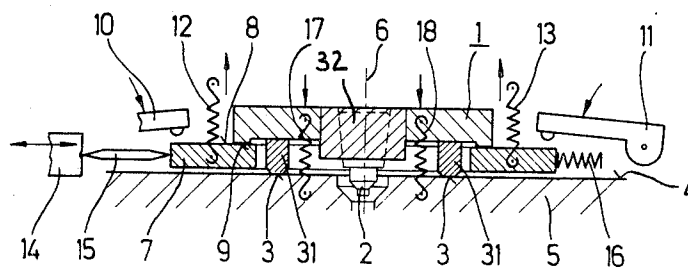


Fig.1

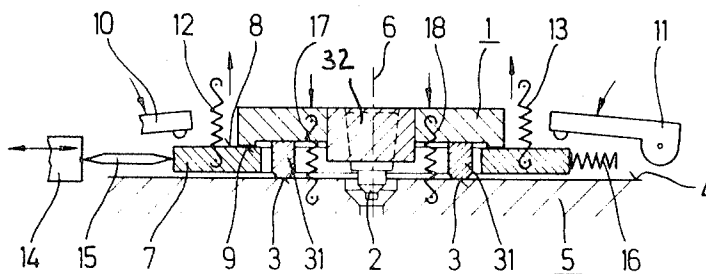


Fig. 2

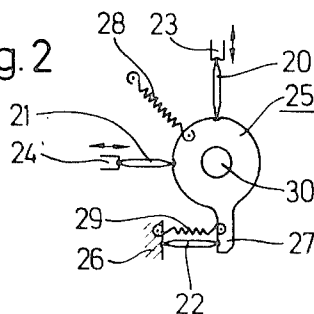
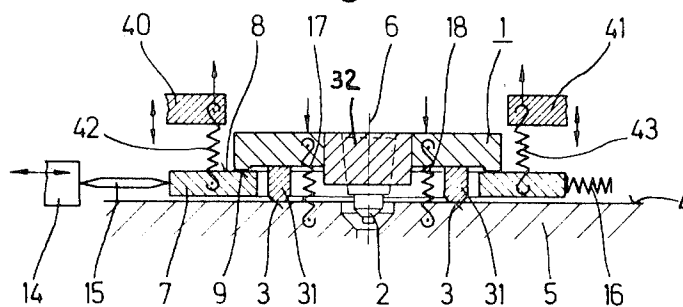


Fig.3



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ADJUSTING DEVICE FOR CORPUSCULAR-BEAM APPARATUS

My invention relates to a corpuscular-beam apparatus such as an electron microscope.

In particular, my invention relates to the structure for adjusting the position of a component such as a specimen-carrying table, so that the specimen which is examined in the microscope can be positioned with respect to the radiation axis of the microscope.

It is known to use in electron microscopes specimen-adjusting devices which generally include adjusting plungers for shifting perpendicularly to the radiation axis a specimen table which slidably engages a supporting surface which is normal to the radiation axis and which primarily is formed by the upper pole surface of the objective of the microscope. This specimen table receives a specimen cartridge which may be introduced into the table either by movement along the radiation axis or by lateral movement by way of a bar which introduces the cartridge into the table. The adjusting plungers, which are generally movable in mutually perpendicular directions in opposition to opposed forces, can be actuated from the exterior of the evacuated interior of the apparatus by way of threaded spindles and by the use of bell cranks, in a purely mechanical manner. However, as may be seen from German Pat. No. 831,424, for example, there are also known constructions where the actuation of the adjusting plungers to bring about movement normal to the radiation axis is carried out directly by hydraulic movements.

Specimen-adjusting devices of this type which permit use of sliding friction have proved to be very successful. However, with increasing resolution powers of electron microscopes the problem of maintaining specimen drift as small as possible is encountered, because of the necessity of preventing undesired movement of the specimen after the adjustment of the position thereof has been completed. Because of the extent to which the development of modern electron microscopes has advanced, it is essential that specimen drift be maintained at a value which is less than 0.1 A/S.

It has been recognized that the reason for the undesired specimen drift is the heating of the specimen and of components such as specimen table, for example. For this reason steps have been taken to provide for a better conduction of heat to other parts of the apparatus (German Pat. No. 1,165,780 and U.S. Pat. No. 3,244,877). Another cause of specimen drift is the exterior vibration of the apparatus. Thus, it is already known from German Pat. No. 1,078,703 to reduce the contact pressure between the specimen table and its supporting surface either pneumatically or hydraulically, while carrying out adjustment of the table, while on the other hand to increase, during all other operating times, the contact pressure between the table and its supporting surface to an extent which will exclude the undesired specimen movement as a result of exterior vibrations.

All of the above attempts to solve the problem have indeed resulted in partial success. However, there still remains the problem of providing a specimen-adjusting structure which will reliably maintain specimen drift below a value which is acceptable for the highest degree of resolution.

It is accordingly a primary object of my invention to provide a structure which will reliably maintain the specimen drift, after adjustments have been made, at a value well below that which can be accepted for the highest resolution power of the apparatus.

In particular, it is an object of my invention to provide a structure which will function in a purely mechanical manner, lending itself to any type of manual or automatic actuation from the exterior of the apparatus, so as to eliminate problems which are encountered with nonmechanical adjusting devices.

Furthermore, it is an object of my invention to provide a desirable nonyielding transmission of adjusting movement to the specimen table or other component which is to be adjusted without, however, requiring any consideration of or compensation for drift which normally would be encountered to a certain extent after termination of the adjusting movement.

It is especially an object of the present invention to provide a structure which will transmit adjusting movement to the table or other component without play when adjusting movements are required while at the same time eliminating any possibility of drift after the adjustment has been terminated.

My invention is particularly concerned with an adjusting device for a corpuscular-beam apparatus, particularly an electron microscope, where there is within the evacuated interior of the device a specimen table which is adjusted perpendicularly to the radiation axis by actuation of mechanical adjusting structure from the exterior of the evacuated chamber. This specimen table slidably engages a supporting surface which is normal to the radiation axis. The concepts of my invention and test carried out in accordance therewith have demonstrated that the above objects can be achieved by making use of a clutch which transmits movement from the adjusting structure to the specimen table, in a play-free manner, only when the clutch is engaged, while the clutch has a disengaged position preventing any transmission of movement to the table. The clutch preferably includes a movable clutch plate of endless configuration which has a permanent operative connection with the adjusting structure and which has a clutch surface directed away from and extending parallel to the supporting surface which is slideably engaged by the table and which is normal to the radiation axis. The table itself has a complementary clutch surface directed toward the supporting surface to be engaged by the clutch surface of the clutch plate when the latter is displaced away from the supporting surface to a position where the clutch is engaged. A clutch-actuating structure coacts with the clutch plate to move the latter between its engaged and disengaged positions only in a direction perpendicular to the supporting surface which is slideably engaged by the table, so that in the disengaged portion of the clutch means the above clutch surfaces are spaced from each other while the movement can be transmitted from the adjusting means through the clutch means to the table only when the clutch means is in an engaged position with the above clutch surfaces engaging each other.

My invention is based on the recognition of the following phenomena:

Up to the present time it has been supposed that movement of the specimen table only comes about when a given minimum force is transmitted from the adjusting structure to the table, with this force being sufficient to produce the sliding movement of the table with respect to its supporting surface. In contrast, however, with a development of my invention it has become known that extremely small movements, referred to below as micromovements, are encountered as a result of transmission of any small forces from the adjusting structure to the table, even if these forces are considered to be insufficient to bring about actual sliding movement of the table with respect to its supporting surface.

These micromovements are the result of three factors:

The first factor is that of elasticity which to a very great extent depends upon the materials and the condition of the surfaces which slidably engage each other. Only in the case of plastics does this value have a magnitude substantially greater than for other materials which are of interest in this connection, namely metals.

The second factor is an irreversible factor depending to a great extent on the materials, the contact pressure therebetween, and the condition of the surfaces which slidably engage each other.

Finally, the third factor is formed by a time-dependent tendency of the table to carry out followup movements, this factor depending to a large extent on the materials, and the condition of the surfaces which slidably engage each other (including the purity and cleanliness of these surfaces), and the magnitude of the forces which act perpendicularly to the surfaces which slidably engage each other. In this case also plastics have relationships which differ in this connection from other materials which are of interest, since in the case of plastics (similarly to the case of soft metals) this third com-

ponent which contributes to the micromovements can be so great that upon disappearance of the adjusting movement parallel to the slidably engaging surfaces a reverse movement takes place. When using hard materials, however, it is possible to eliminate this component of micromovement by reducing the force below a given value, as a rule half the value of the force required to produce any slidable movement.

Because of these different factors which determine the individual components which contribute to any micromovements, it is practically not possible to completely eliminate the micromovements through a selection of the materials used for the coating components where these components slidably engage each other and it is also not possible to eliminate such micromovements by way of the manner in which the slidably engaging elements are worked or operate.

With my invention these conditions are taken into consideration by providing between the table or other element which is to be moved, on the one hand, and the adjusting or moving means, on the other hand, a clutch which brings about a complete cutting off of any possible transmission of movement from the adjusting means to the table after adjusting movement thereof has been completed, so that the table is free of the action of the driving forces of the adjusting means after the adjustment is completed. In this way it is possible to achieve a complete elimination of one of the factors which is required for any type of component contributing toward the micromovement, namely the presence of a force acting parallel to the surface engaged by the table. Of particular advantage with this solution of my invention is the achievement of at least an extremely large freedom from drift without sacrificing the range of possible adjusting movement of the table or other component, since with the structure of my invention the clutch means is constructed in such a way that during the different operating times, namely during the adjusting time of the table and during the remaining operating time, the table and the adjusting means form partly a single unit (during adjusting of the table) and partly separate units (during the remainder of the operations). The adjusting means itself can be actuated by hand through threaded spindles or, for example, by step motors or other transmissions which may be specially designed to bring about the required adjusting movements.

It is known to resort to electrical structures for bringing about adjusting movements of a specimen, as described in U.S. Pat. No. 2,496,051 which in a nonmechanical manner permit adjusting forces to be transmitted to the holder of the specimen only during movement of the holder. This is brought about by using magnetostrictive adjusting means the driving coils of which are supplied with a voltage of sawtooth configuration. Depending upon the steepness of these sawteeth, there will be an achievement of small jumps of the specimen in a given direction. Inasmuch as after the adjustment of the specimen has been completed the sawtooth voltage is turned off, there are no longer any forces acting on the holder for the specimen.

This known solution, however, has serious disadvantages. In the first place, it is extremely difficult to screen the magnetic fields of the adjusting means in such a way that they have no influence on the electron ray. Furthermore, the surfaces which slidably engage each other, namely the surfaces of the holder for the specimen and the upper pole shoe of the objective, must be worked in such a way that on one hand it is possible to bring about a relatively easy sliding of the specimen holder during adjustment thereof while on the other hand the influence of exterior vibrations is prevented from disturbing the position of the specimen and moving the latter by providing a sufficiently great friction between these surfaces. Furthermore, it is difficult when the specimen holder rests in a completely free manner on the upper surface of the objective pole shoe to bring about specimen adjustments which can be reproduced both in magnitude and direction.

All these difficulties are avoided with my invention since in this case the clutch plate of the clutch means is guided so that

it remains parallel to the surface on which the table slides and moreover with my invention it is possible to make use of adjusting means which have already proved to be successful in practice.

In this connection it is to be noted that the device of my invention is suitable for use with corpuscular-beam apparatus different from electron microscopes, such as, for example, an ion microscope, diffraction devices, or device working with rays or beams of charge-carrying particles. Furthermore, it is possible to apply my invention to components in the evacuated chamber of an electron microscope other than the components directly associated with the specimen. Thus, my invention can be applied to any components in the evacuated chamber of an electron microscope which require adjusting movement so that my invention can be used, for example, to bring about adjustment of a diaphragm, in which case the "table" takes the form of the holder of the diaphragm.

My invention is illustrated by way of example in the accompanying drawings which form part of this application and in which:

FIG. 1 is a fragmentary schematic sectional elevation of one embodiment of the invention taken in a plane which contains the radiation axis;

FIG. 2 is a schematic plan view illustrating the manner in which the adjusting means is operatively connected with the clutch plate of my invention; and

FIG. 3 is a fragmentary schematic sectional elevation, also taken in a plane which contains the radiation axis, of another embodiment of my invention.

Referring first to FIG. 1, the specimen adjusting table 1 in this embodiment is provided with a specimen in a cartridge 2 which is received in the table 1 with the specimen situated at the lower end of the cartridge 2. The table 1 has three supporting feet 3 the bottom ends of which engage the supporting surface 4, which in this example is formed by the upper surface of the upper objective pole shoe 5. The radiation axis 6 extends perpendicularly with respect to the supporting surface 4 and thus with respect to the direction of adjusting movements of the table 1.

In accordance with my invention there is a clutch means which includes the clutch plate 7 which in this embodiment of my invention extends into a space which is defined between the table 1 and the supporting surface 4. It is also possible, however, to guide the clutch plate 7 in an opening such as an annular groove formed in the outer periphery of the table 1 and having a dimension perpendicular to the surface 4 which is great enough to provide the required displacement of the clutch plate 7 toward and away from the surface 4 between disengaged and engaged positions.

Thus, the dimension of such a groove or opening, or of the space between the table 1 and the surface 4, in the embodiment of FIG. 1, is sufficiently great to permit the required movement of the clutch plate 7 perpendicularly to the surface 4. Such movements make it possible to displace the upper clutch surface 8 of the clutch plate 7, namely the surface thereof which is directed away from the supporting surface 4, into engagement with the clutch surface 9 which forms part of the table 1 and which is directed toward the surface 4, these clutch surfaces 8 and 9 of course forming part of the clutch means of my invention. When these surfaces engage each other the clutch means is in its engaged position capable of transmitting adjusting movement to the table 1 while when the surface 8 is displaced away from the surface 9 so as to be out of engagement therewith the clutch means is disengaged and there will be an interruption in the transmission of any possible movement to the table 1 without any possible vibrations thereof.

In order to bring about the movement of the clutch plate 7 between its engaged and disengaged positions, a clutch-actuating means is provided. In the example of FIG. 1, this clutch-actuating means includes a pair of clutch levers 10 and 11. These levers are assembled so as to have a fork-shaped configuration providing three points of engagement between

the clutch-actuating means 10, 11 and the clutch plate 7 at points which are equidistantly spaced at 120° from each other, for example, about the radiation axis 6. Through suitable transmissions accessible at the exterior of the evacuated chamber, such as by turning of one of a pair of parallel shafts respectively fixed to the levers 10 and 11 and interconnected with each other by gears to being about equal and opposite directions of turning movement of the levers 10 and 11, it is possible to bring the clutch-actuating means 10, 11 into the illustrated position of FIG. 1 where they are out of engagement with the clutch plate 7. Therefore at this time a spring means 12, 13 can act to bring the surface 8 into engagement with the surface 9 and to hold the surface 8 in engagement with the surface 9. Thus, with this embodiment it is the spring means 12, 13 which displaces the clutch means into and holds it in its engaged position. The number and arrangement of the springs 12, 13 are such that the clutch plate 7 is displaced into its engaged position while moving at all times perpendicularly with respect to the surface 4, and of course the actuating means 10, 11 also acts on the plate 7 to displace the latter perpendicularly toward the surface 4 into the disengaged position.

In the illustrated example the adjusting means for bringing about movement of the table 1 is primarily in the form of driving plungers, adjusting rods and opposing springs. Thus in FIG. 1 in order to bring about movement of the table 1 to the right and left, the illustrated plunger 14 acts horizontally through the rod 15 directly on the plate 7 which opposite to the rod 15 is acted upon by the compressed spring 16 which maintains the outer periphery of the plate 7 pressing against the inner end of the rod 15 whose outer end is maintained in this way in engagement with the plunger 14. In this way a mechanical adjusting means which has proved successful in practice can be used.

Furthermore, the springs 12, 13 bring about a lessening of the contact pressure between the feet 3 and the surface 4. This reduction in the contact pressure between the specimen-carrying table and the surface 4 during adjusting movement makes it possible to use with the structure of my invention tension springs 17, 18 which urge the table 1 toward the surface 4 to bring about a secure, reliable support of the table 1 during photographic exposure of a specimen in the electron microscope. Of course, instead of tension springs 17, 18 it is possible to use compression springs situated above the table 1 and urging the latter downwardly toward the surface 4.

On the other hand, during examination of a specimen the clutch is in its disengaged position where the surface 8 does not engage the surface 9 so that at this time any transmission between the adjusting means 14-16 and the table 1 is completely eliminated and thus micromovements are entirely excluded.

The several components of the adjusting means, including components 15, 16, are arranged in such a way with respect to the clutch plate 7, which in this case has the configuration of a ring, that positive, predetermined precise adjusting movements of the clutch plate 7 and table 1 are brought about. By way of example, one embodiment of the structure for carrying out this principle is shown at a different scale in FIG. 2. In this example the adjusting means includes three adjusting rods 20, 21 and 22 all located in a plane parallel to the supporting surface. The rods 20 and 21 are perpendicular to each other and extend from the outer periphery of the clutch plate 25 to the adjusting plungers 23 and 24, respectively, while the third rod 22 is parallel to the rod 21 and is situated between the stationary component 26 of the device and a radial extension 27 of the ring-shaped clutch plate 25. Springs 28 and 29 act on the clutch plate 25 so as to maintain the rods 20, 21, 22 compressed between the components which engage their outer ends and the edge of the plate 25 at their inner ends. These springs 28, 29 are respectively connected at their inner ends with the plate 25 and at their outer ends to stationary components of the device, the inner ends of the springs 28, 29 having pivotal connections with the plate 25 so that these inner ends of the springs 28, 29 are capable of turning with respect to the plate 25.

All of the rods 20, 21 and 22 carry at their inner ends ball members which are freely turnable in conical or partly spherical recesses of the rods and the periphery of the table 25 so that in this way the rods permit the clutch plate 25 to carry out small swinging movements with respect to the adjusting plungers 23 and 24. The specimen cartridge extends in this case also into the opening 30 of the clutch plate 25.

With the structure of my invention the adjusting means which brings about the movement of the clutch plate 7 of FIG. 1 also is constructed so that it guides the clutch plate 7 for vertical movement between its disengaged and engaged positions while maintaining the clutch plate 7 at all times parallel to the surface 4 so that a special guiding structure need not be provided for this purpose. Therefore with the structure of my invention the clutch operates in such a way that the clutch surfaces 8 and 9 come simultaneously into engagement over the entire area where they engage each other or are out of engagement throughout the entire area.

As was pointed out above, the levers 10 and 11 will be actuated from the exterior. It is particularly advantageous to provide the driving transmission for the levers 10 and 11 through operation of a foot switch. Of course, it is possible to achieve all of the required movements of the structure in a purely mechanical manner or by way of electrical devices such as suitable adjusting motors.

It is also possible to provide a construction where the action of the springs 12 and 13 and the clutch levers 10 and 11 is reversed so that upon actuation of the clutch levers 10 and 11 the clutch surfaces 8 and 9 are brought into engagement with each other. Such an embodiment of my invention is illustrated in FIG. 3 where those elements which have already been described in connection with FIG. 1 are indicated by the same reference characters. The clutch-actuating levers 40, 41, which also are assembled to provide fork-shaped configuration, in this case do not directly contact the clutch plate 7, but instead are connected to the latter through the tension springs 42 and 43. Of course, instead of springs which are under tension it is also possible to use springs which are under compression. Then the movement of the surface 8 and 9 into engagement with each other would be brought about by upward movement of the levers 40, 41. Of course, with the arrangement of FIG. 3, the springs 42 and 43 urge the plate 7 into its upper engaged position, while downward movement of the levers 40, 41 will reduce the tension force of the springs 42, 43 to an extent which will enable the clutch 7 to be lowered away from the surface 9 to its disengaged position.

In order to further reduce the extent of specimen drift the table is made of a preselected material which has the same coefficient of thermal expansion as the supporting surface 4. For this purpose the legs 31 of the table 1, which provide the supporting surfaces 3 thereof, as well as the central insert 32 which carries the cartridge 2 are made, for example, of bronze while the remaining elements can be made of molybdenum. Experience has shown that with such a selection of materials it is possible to achieve and extremely close equality to the thermal coefficient of expansion of the pole shoe iron of the component 5.

It is also possible to make advantageous use of bar springs for the springs of the assembly of my invention. Also, it is to be understood that my invention can be used for adjusting structure other than specimen-holders, such as, for example, a diaphragm as referred to above.

I claim:

1. In a corpuscular-beam apparatus, and in said apparatus a source of electrons and a specimen to be investigated, a supporting surface situated in a plane normal to the radiation axis of the apparatus, a specimen table slidably engaging said surface for movement thereon, adjusting means located adjacent said surface for adjusting said table thereon with respect to said axis, and clutch means coacting with said adjusting means and said table for transmitting movement from said adjusting means to said table only when said clutch means is in an engaged position where said clutch means provides a play-free transmission of movement from said adjusting means to said

table, said clutch means having a disengaged position in which said table is completely out of operative connection with said adjusting means through said clutch means and remaining in the disengaged position after adjusting of the table by the adjusting means, so that adjusting movement of said table can only be brought about when said clutch means is in said engaged position thereof, said clutch means remaining disengaged during investigation of a specimen.

2. The combination of claim 1 and wherein said clutch means includes a movable clutch plate of ring-shaped configuration permanently in operative connection with said adjusting means and having a clutch surface directed away from and extending parallel to said supporting surface on which said table is slidable, said table having directed towards said supporting surface and said clutch surface of said clutch plate a complementary clutch surface parallel to said supporting surface and engaged by said clutch surface of said plate when said clutch means is in said engaged position, and clutch-actuating means coacting with said clutch means for displacing the latter perpendicularly to said supporting surface between a disengaged position where said clutch surfaces are spaced from each other and an engaged position where said clutch surfaces engage each other, so that only in the latter engaged position can movement be transmitted from said adjusting means to said table.

3. The combination of claim 2 and wherein said table and said supporting surface define between the latter and said clutch surface of said table a free space into which said clutch plate extends, said free space having in the direction of the radiation axis a dimension sufficiently great to provide for movement of said plate to and from a position where said clutch surface thereof engages said clutch surface of said table to provide for engagement and disengagement of said clutch means.

4. The combination of claim 2 and wherein said clutch-actuating means includes a spring-and-lever assembly having springs operatively connected with said clutch plate for urging the latter to one of its positions and levers adapted to be actuated from the exterior of the apparatus for bringing about movement of the clutch plate to the other of its positions.

5. The combination of claim 4 and wherein the springs and levers of said spring-and-lever assembly coact with said clutch plate for guiding the latter perpendicularly with respect to said supporting surface during movement of said clutch plate between said engaged and disengaged positions of said clutch means.

6. The combination of claim 5 and wherein the springs of said assembly act on said clutch plate to urge the latter into engaged position of said clutch means where said clutch surfaces engage each other.

7. The combination of claim 4 wherein said springs of said

assembly are connected between said clutch plate and the levers of said assembly and have with respect to said clutch plate and levers a relationship providing for guiding of said clutch plate perpendicularly to said supporting surface during movement of said plate to bring about said engaged and disengaged positions of said clutch means.

8. The combination of claim 2 and wherein a spring means acts on said table for urging the latter perpendicularly toward said supporting surface.

9. The combination of claim 2 and wherein said clutch plate of ring-shaped configuration has an extension projecting radially from its outer periphery, said adjusting means including three adjusting rods located substantially in a plane parallel to said supporting surface with one of said rods permanently engaging said extension of said clutch plate and with the other two rods being perpendicular to each other and permanently engaging the periphery of said plate, one of said other two rods being parallel to said one rod which engages said extension, said adjusting means further including a pair of mutually perpendicular actuating plungers respectively terminating in free ends engaging ends of said other two rods distant from said clutch plate and coacting with said other two rods for moving the latter axially in opposed mutually perpendicular directions, a stationary component engaging the end of said rod which is distant from said extension, and spring means coacting with said clutch plate for maintaining the latter permanently in engagement with said rods and for maintaining said other two rods permanently in engagement with said plungers and said one rod permanently in engagement with said stationary component.

10. The combination of claim 1 and wherein said table and supporting surface have the same coefficient of thermal expansion.

11. In a corpuscular-beam apparatus, and in said apparatus a source of electrons and a specimen to be investigated, a supporting surface normal to the radiation axis of the apparatus, a component slidably engaging said surface for adjustable movement perpendicularly to said axis, adjusting means for adjusting said component, and clutch means having an engaged position for transmitting movement between said adjusting means and said component, said clutch means having a disengaged position preventing any transmission of movement from said adjusting means through said clutch means to said component and remaining in the disengaged position after adjusting of the component by the adjusting means so that the latter can be adjusted with respect to said axis only when said clutch means is in said engaged position thereof, said clutch means remaining disengaged during investigation of a specimen.

12. The combination of claim 11 and wherein said component is a diaphragm.

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