April 26, 1966 W. C. NIXON 3,248,542

ELECTRON BEAM DEVICES HAVING PLURAL CHAMBERS DESIGNED TO BE ASSEMBLED AND DISASSEMBLED

Filed March 20, 1963 4 Sheets-Sheet 1

Fig. 1.

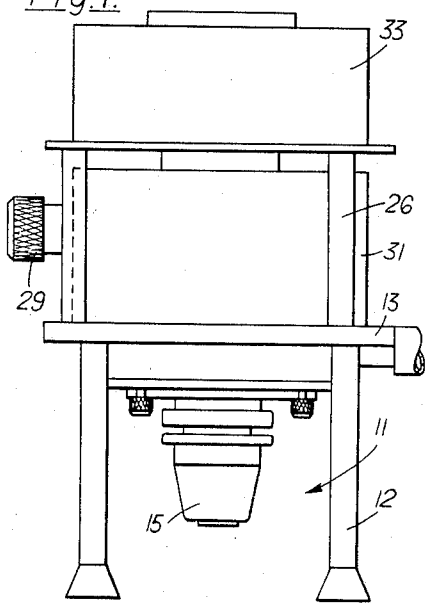

Fig. 2.

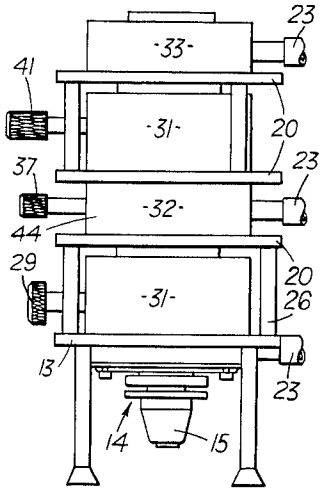

Fig. 3.

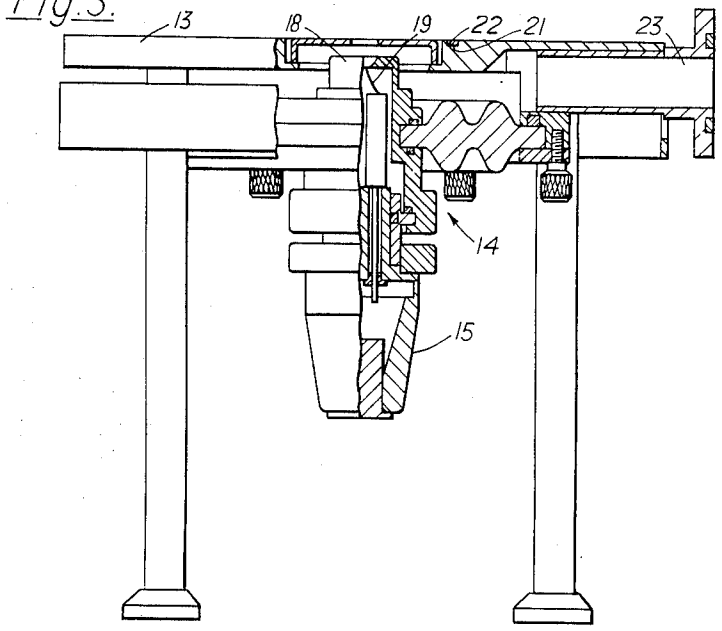

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Fig. 4.

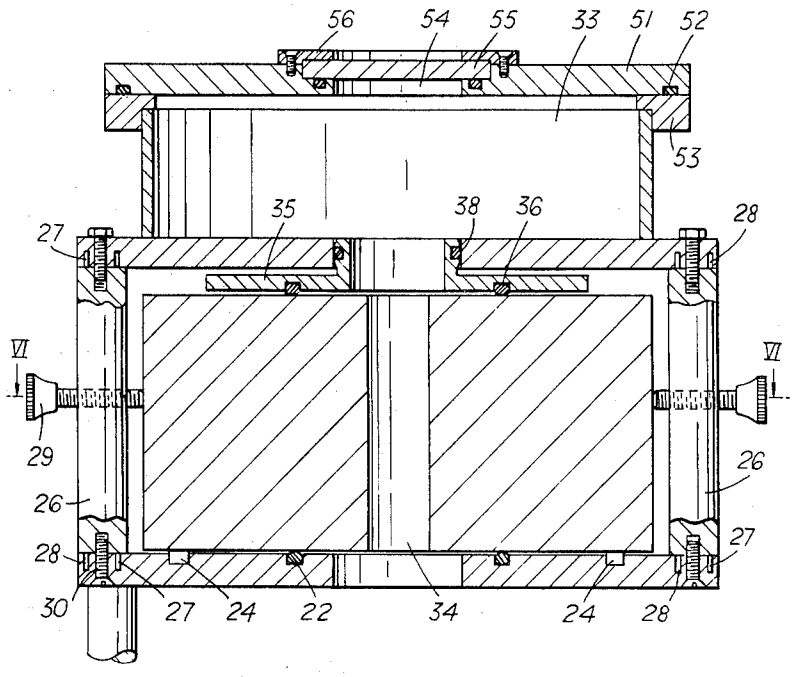

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Fig. 5.

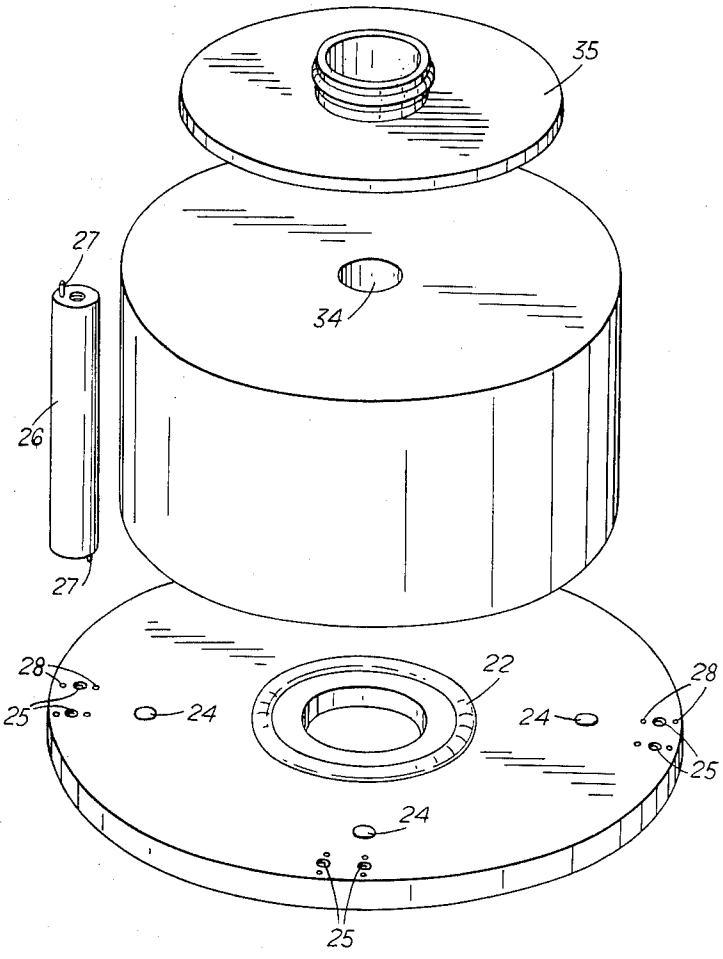

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Fig. 7.

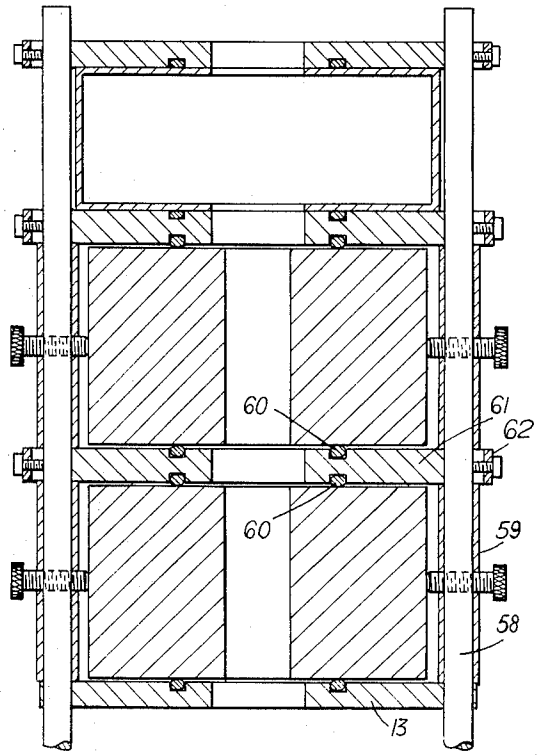
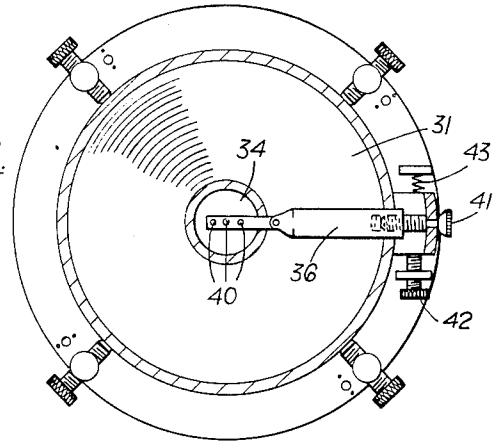


Fig. 6.



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3,248,542

ELECTRON BEAM DEVICES HAVING PLURAL CHAMBERS DESIGNED TO BE ASSEMBLED AND DISASSEMBLED

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Filed Mar. 20, 1963, Ser. No. 266,621
11 Claims. (Cl. 250—49.5)

The present invention relates to electron beam equipment, that is to say, apparatus where an electron beam is produced in an evacuated envelope, the electrons emitted by an electron source being concentrated or focussed to form a narrow pencil of electrons. Such equipment may be used in a wide variety of applications for scientific, medical and industrial purposes, and may be used, for example, for the examination or assessment of specimens or for performing shaping or cutting operations on metal or other workpieces.

Typical examples of the application of such equipment are for projection X-ray microscopy, divergent beam X-ray diffraction, microfluoroscopy, high source brightness contact microradiography, static or scanning X-ray micro-analysis by emission, absorption or fluorescence of X-radiation in a small selected area, cathodoluminescence, microcircuit etching, drilling of small holes or slots, microforming by electrons, transmission or reflection at glancing or normal incidence, electron diffraction with or without scanning of the pattern, or scanning electron microscopy.

Basically, the various types of equipment required for carrying out such examples of applications comprise an electron gun as a source of electrons, and a limited range of other components housing ancillary equipment, the detail arrangement of which is dependent on the particular purpose which the equipment is intended to fulfil, as well as associated electrical power supply equipment for providing a high voltage for accelerating the electron to high speeds and for operating a heater forming part of the gun, and associated vacuum pumping equipment.

Typical examples of such ancillary equipment comprise beam focussing elements generally referred to by optical analogy as lenses, while the said other components may include apertures, stigmators, fluorescent viewing screens, photographic plate or film holders, specimen or work stages, scanning coils or plates, and alignment coils or plates, but the foregoing list is by no means exhaustive and is only intended to summarise the type of ancillary equipment which may be required.

Such electron beam equipment as heretofore constructed, has in most cases been designed for one particular type of investigation or for one particular type of functional purpose and in general an apparatus designed and constructed for one purpose cannot be utilised for any other related purpose despite the fact that for carrying out any of the wide range of functions that can be performed by this range of equipment there are many parts which are common to the different types of equipment, although they may have to be arranged in different positions or in different orders.

The object of the present invention is to provide means for improving the versatility of electron beam equipment of the character referred to whereby a wide range of functions can be performed by a relatively small range of equipment.

In accordance with the present invention electron beam equipment is provided which is arranged so that at least one component is exchangeable and can be replaced by another component.

In preferred forms of the invention the equipment as a whole or at least the ancillary components thereof are

formed by the assembly of separate component parts, all of which are designed so that they can be assembled and disassembled, one component can be replaced by another component, the relative positions of some of the components can be changed, and some of the components may be arranged to receive various types of ancillary equipment.

The equipment according to the present invention may thus be utilised in various ways and for carrying out various investigations or operations. In many cases the components may be arranged so that a convergent electron beam is formed for purposes where an electron probe or point focus instrument is required such as the applications outlined above, but in other cases a divergent electron beam may be produced so that the electron beam is not arranged for a point focus, but is arranged to produce a magnified image for high resolution electron microscopy by transmission, reflection, thermionic emission, mirror interference, secondary emitted electron contrast formation due to ion bombardment, ultra-violet light or other means of ejecting electrons or for electron optical experiments involving the interaction of the electron beam with a magnetic and/or electrostatic field.

In these various types of equipment the equipment includes magnetic lenses variously placed according to requirements and the work or specimen stage may be placed intermediately of several lenses or may be placed beyond the lenses as seen from the gun.

Furthermore, in carrying the present invention into effect the components, or at least the replaceable and removable components thereof, are formed in such a way that they are adapted to be assembled in vacuum sealing arrangement one with the other so that the complete envelope is formed by the assembly of such components.

The present invention also comprises electron beam equipment in which the electron beam is directed along a vertical or nearly vertical axis, and in the preferred arrangement the electron gun is located at the lower end of the equipment, the beam being directed in the upward direction so that the removable and/or interchangeable components forming the main part of the envelope through which the beam is directed, can be removed or replaced from above, the whole column so formed being supported from the base, or preferably from a support member to the under side of which the electron gun is fitted, and in this case the electron gun itself may be removable and replaceable by another electron gun unit.

Where the electron gun is arranged at the base of the column in this way the support for the gun forms the main support for the column, the gun being attached to the underside of the support, while the various items of ancillary equipment which are built up to form the complete equipment are supported from the upper face of said support.

The said support for the gun may be suitably mounted from a fixed carrier or stand and said stand may be associated with or may itself house the power supply equipment for operating the electron beam equipment, as well as vacuum exhausting equipment for exhausting the envelope after the equipment has been assembled in such a way that the exchangeable components have been assembled to form a complete envelope.

Some or all of the components may be in the form of containers closed peripherally and housing the particular equipment concerned, the end faces of such components being adapted to have a vacuum sealing engagement with other parts of the components of the complete equipment, thus forming the envelope for the equipment.

Alternatively, at least part of the envelope can be formed by a tubular section surrounding the path of the electron beam, other components being adapted to be

placed over this tubular section, for example magnet or electro-magnet lens units, which in this case need not be in vacuum sealing engagement with the other components, and such a tabular section may be fixedly or adjustably associated, for example, with the gun support, the upper end of the tube being arranged to come into vacuum sealing engagement with a further component placed above a non-vacuum sealed component located around said tubular section.

Preferably, however, the equipment will embody two or more components adapted to be brought into sealing engagement one with the other, and for this vacuum sealing function it is preferable to utilise O-ring sealing members inserted in the one flat face of each component and adapted to be engaged with the flat face of an adjacent component.

Then the complete equipment may be formed by assembling an appropriate range of components one upon the other, the O-ring seals on each component providing a seal against the component adjoining it, the complete equipment thus including an electron gun at the base, a plurality of components all in vacuum sealed arrangement one with the other to form the envelope, and, of course, a suitable top closure member which may be formed by one of the components.

In many cases it may be desired that one component should be reversible in relation to another component. This requirement arises, for example, in the case of lenses which are generally non-symmetrical about a central transverse plane, in which case the possibility of reversing the lenses avoids the necessity of duplicating the lens equipment to fulfill a wide variety of functions since often one lens component can be reversed in position to secure a required focussing effect without having to provide a second lens component to perform some specialised function.

An assembly produced according to the invention may be in the form of a column built up of the component elements required to perform a specified function and intermediate elements provided as required between adjacent components, these intermediate elements incorporating O-ring seals. In all cases the column may be closed by a top closure unit which in many cases may be a work-chamber. The intermediate elements may be, for example, specimen stages or work-holder stages, and in fact some of the effective parts of the complete system may be carried by such intermediate elements while other essential parts of the system are formed by the main components. In general, the main components will comprise lenses, stigmators, scanning or alignment coils and so on, whereas other parts of the equipment which do not occupy a great deal of space or which are relatively light, such as plate or film holders or specimen or work stages, can be removably associated with intermediate elements or with a top closure unit.

In constructional arrangements according to the invention column means may be provided to absorb independently the weight of each component of the assembly. This is desirable because if lens components and intermediate elements are assembled in direct contact the various units have to support the weight of the units above it, and this pressure coupled with the high internal vacuum may tend to press the components so firmly one against the other that any slight adjustments necessary such as translatory movements of the lenses cannot be effected.

It will be understood that all the units referred to are reversible and interchangeable and the required assembly or column may be built up according to requirements from a limited number of basic components and auxiliary units. Other additional components such as work chambers or the like, or special lenses can be added where particular requirements are to be met. Because the main components are standardised they can be produced in greater quantities than would be the case where complete equipment is specially built, these components can be produced at a lower cost than heretofore.

Work chambers or intermediate units can be fitted with

means for the attachment to the vacuum pump and for installing electrical leads or astigmatism leads where they have to enter into the vacuum envelope.

The features of the present invention are illustrated by way of example on the accompanying drawings showing various ways of assembly of the component units, together with the construction of such units and component parts whereby various types of equipment can be assembled for performing various operations according to the particular requirements which may arise at any particular time.

FIG. 1 is an outline view showing one arrangement of the equipment,

FIG. 2 is an outline view illustrating an alternative arrangement,

FIG. 3 is a detail section illustrating the construction of the base stand with the electron gun unit,

FIG. 4 is an enlarged view showing the arrangement of certain parts as typical arrangement of the equipment to show the constructional details of the mounting and interconnection of the various parts, and

FIG. 5 is an exploded view in diagrammatic perspective showing an electron lens and a stage plate,

FIG. 6 is a cross-section on line VI—VI of FIG. 4 to show details of electron beam regulator elements, and

FIG. 7 is a diagrammatic view illustrating an alternative form of construction.

The present invention is based on the selection and assembly of various standardised component parts and units to form a range of electron beam equipment capable of performing various functions, and it comprises a base stand **11** having a plurality of upright columns **12** supporting a top plate **13** beneath which an electron gun unit indicated in general at **14** is mounted. This electron gun unit may be removable and interchangeable and is of conventional construction and includes an outer casing **15** to the base of which the high tension feed cable is attached. This casing houses a Wehnelt cylinder **18** and a filament **19**. These parts are suitably supported to operate at a high potential to earth and are adapted to produce an upwardly directed beam of electrons. Vacuum connections are shown at **23**, leading to the gun unit **14**, and preferably to intermediate chambers **32** and the top chamber **33**.

The upper face of the plate **13** is arranged to accommodate in sealing manner other components placed on top of it, and a similar arrangement is adopted for the intermediate stage plates **20** to be referred to hereinafter. The construction of these stage plates **20** and of the top plate **13** will now be described. The upper face of the plate is provided with an annular groove or channel **21** adapted to receive an O-ring **22** of the type commonly employed in high vacuum practice. A spaced series of low friction elements **24** (FIGS. 4 and 5) are provided in the upper surface of the plate, the top surface of these low friction elements being slightly proud of the surface of the plate so that a component rests on these elements rather than on the plate itself and permits satisfactory vacuum sealing with the O-ring **22**. These low friction elements **24** may consist, for example, of polytetrafluoroethylene.

A series of apertures **25** are provided in the top plate **13** whereas in the case of intermediate stage plates pairs of such apertures are provided, as shown on FIG. 5. These apertures are adapted to receive screws **30** for fastening spacer columns **26** to the plate **13**, or to the intermediate plates, each spacer column being provided at each end with an off-centre peg **27** adapted to enter either of a pair of apertures **28** disposed on each side of the apertures **25** so that the fixing screws **30** can be tightened without involving inadvertent rotation of the columns **26**. The columns **26** may be provided with transversely disposed adjusting screws **29** whereby components, particularly magnetic lenses **31**, may receive translation adjustment on the plate **13** or on the inter-

mediate stage plates 20 adjustment of any lens 31, for example, being independent of other lenses.

The stage plates 20 referred to are constructed in substantially the same way as the top plate 13 except that as already indicated, they have pairs of apertures 25 to receive columns extending both upwardly and downwardly as may be required when two magnetic lenses 31 are placed one over the other. It has not been deemed necessary to illustrate an arrangement where two lenses 31 are placed successively. In such cases a stage plate 20 extends between the two lenses, with columns 26 extending up and down.

The top plate 13 or the stage plates 20 are adapted to receive various components, selected from magnetic lens units 31, intermediate chamber units 32 and top chamber units 33, and typical examples of such assemblies are illustrated on FIGS. 1 and 2. It will be observed, however, that in general the column of components is closed at the top by means of a top chamber unit 33. The magnetic lens units 31 are constructed in accordance with normal practice in electron beam equipment and comprise a central tunnel 34 providing the passageway through which the electron beam is directed from the electron gun unit associated with the base stand 11, and flat end faces, and these lens units are in the form of substantially closed boxes housing a magnetizing coil receiving a magnetizing current from a source, not shown, together with removable pole pieces incorporating peripheral gaps in the bore. These parts are arranged in well-known manner and it has not been thought necessary to show them in detail.

These pole pieces may be arranged towards one end of the magnet unit and thus it becomes possible for each lens to exert a different focussing action on the electron beam according to which end of the magnet is placed uppermost.

Each lens unit is of less height than the length of the spacer columns 26 and the free space so left is completed by means of a filler member 35 which is in the form of a short tubular portion, the bore of which coincides with the axis of the tunnel 34, and a flanged rim portion. The under face of the flanged rim portion is provided with an O-ring seal 36 and the peripheral part of the cylindrical portion is of slightly convex form and incorporates a further O-ring seal 38 adapted to seal against the central aperture in a stage plate 20. It will be seen that this filler member 35 provides efficient sealing between the components without, however, involving the need for an extremely high degree of accuracy in production.

Each magnetic lens 31 may be associated with a transversely disposed beam adjusting device in the form of a stem 39 having a plurality of apertures 40, as indicated on FIG. 6, and which is adapted to be moved in the radial direction by means of an adjusting screw 41 to select one of the apertures 40. This stem 39 is movable about an intermediate axis by virtue of a suitable mounting, and angular adjustment of the stem may be effected by means of an adjusting screw 42 operating against a spring 43 whereby the position of one of the apertures 40 may be adjusted. This assembly of parts provides for accurate correction of the electron beam path through the lens.

The intermediate chamber units 32 may form part of the assembly as shown in FIGS. 2 and 5. Such chambers may be arranged to house a work or specimen holder or a wide range of ancillary equipment such as may be required for the particular work or investigation. Such chamber may comprise a peripheral wall portion 44 and end plates which are substantially similar to the stage plates 20, that is to say, the end plates are provided with single apertures 25 or pairs of apertures 25 to receive spacer columns 26, together with the low friction elements 24. The internal arrangement of the intermediate chamber units 32 may be designed to permit various types of work or specimens, or ancillary equipment to be accommodated therein according to the particular type of work intended to be undertaken. They may, for example, comprise a thin target capable of providing a source of X-rays which is collimated and then strikes a very small area of the specimen to excite a proportional counter placed to one side of the specimen. In the case of a workpiece or a specimen, various adjustments may be provided so that the work may be accurately adjusted in position relatively to the axis of the electron beam to permit various operations to be performed. Such means may involve at least one adjusting member 37. Typical arrangements of intermediate chambers house ancillary equipment such as apertures, stigmators, fluorescent viewing screens, photographic plate or film holders, specimen or work stages, scanning coils or plates, and alignment coils or plates.

A column formed by the assembly of one or more lenses and optionally one or more intermediate chambers is closed at the top by means of a top chamber unit 33 which in some cases may serve as a work chamber particularly where types of investigation are in progress directed to the focussing of a beam of electrons to a point on a specimen or workpiece. On the other hand in arrangements where it is desired to produce an enlarged image, for example as in electron microscopy, the top chamber may be associated with viewing equipment for examination of the magnified image or means for photographing such an enlarged image.

In view of the wide range of constructions which may be adopted for such a top chamber, reference will only be made here to the structural details of the chamber without specifying the type of equipment that can be incorporated therein. As shown in FIG. 4 such a top chamber unit 33 embodies a peripheral wall portion 48 fixed to a base plate 49 which functions in the same way as a stage plate 20. A cover plate 51 is sealed against a flange 53 attached to the peripheral wall 48 by means of an O-ring seal 52 and centrally of the upper face of the top member there may be a glass or other suitable inspection window 54 located in a rebated housing where the glass window is sealed by an O-ring seal 55 and is held in place by a bezel 56.

The invention is not limited to the specific constructional details shown on FIGS. 1 to 6 as a somewhat different arrangement is illustrated on FIG. 7. In this case the top plate 13 is attached to a series of upwardly directed columns 58 of a sufficient length to accommodate the various components which may be required to form a variety of complete sets of apparatus. Spacer tubes 59 are adapted to be placed over the columns 58 and in this case stage plates 61 are used which are adapted to be placed upon the columns 58 where they are supported by the spacer tubes 59. The stage plates 61 are provided in this case with sealing O-rings 60 on both faces and with depressions around the edge to fit over the columns 58. Clamp devices 62 are provided on the stage plates 61 which are adapted to grip the columns 58 after the plates 61 have been placed in position, thereby ensuring proper stability of the structure. In this case, lenses 31, intermediate chambers 32 and the top chambers or work chambers 33 may be arranged as in the manner already described in connection with FIGS. 1 to 6.

What I claim is:

1. Electron beam equipment comprising an electron gun structure having a horizontal support surface forming a stage plate at the upper end thereof, a selected number of other stage plates supported parallel above said former stage plate, a magnetic lens supported on any of said stage plates and a terminal upwardly closed work chamber arranged above said stage plates, all said parts forming an evacuable envelope including the electron gun structure, wherein the bottom stage plate carries a plurality of upright columns, further comprising intermediate plates vertically movable on said columns, spacer elements surrounding said columns accurately to determine the position of said stage plates, components supported in

vacuum sealing manner between said stage plates, clamp means to secure said stage plates to said columns and to said terminal chamber at the top of said column to provide a closed evacuable space within said components to form an operative electron beam structure.

2. An electron beam device comprising an electron gun structure having a top surface forming a first stage plate adapted to receive other components, a plurality of further stage plates arranged parallel to and above said first stage plate to define a vertical column of components, a magnetic lens resting on one of said stage plates in vacuum sealing contact therewith, vacuum tight sealing filler means between said magnetic lens and the stage plate immediately above it, an intermediate chamber disposed in vacuum sealing contact above another of said stage plates, the upper surface of said intermediate chamber forming a vacuum tight seal with a further stage plate, a closed work chamber forming the top element of the column of components overlying the electron gun structure and in vacuum sealing contact therewith, said magnetic lens and intermediate chamber being selectably therefor removable to arrange in variable order to provide a range of different types of equipment exerting different focussing action on the beam and vacuum sealed adjustable means to displace said magnetic lens on said one stage plate, and vacuum connections to several points of the column of components to evacuate air from within the column when said column is assembled.

3. An electron beam device according to claim 2 comprising means to support a specimen in the top work chamber, the components being arranged to produce a convergent electron beam directed on said specimen, said work chamber including means for assessing the response of the sample or specimen to said electron beam.

4. An electron beam device according to claim 1, comprising means to support a specimen in an intermediate chamber, the components in the column being arranged to produce a magnified image of said specimen in the top chamber and means therefor included with said top chamber to evaluate the magnified image.

5. An electron beam device comprising an electron gun structure adapted to project an upwardly directed beam of electrons, said structure having a flat top surface having a central aperture and a facial groove surrounding said aperture, a sealing ring disposed in said groove, an exchangeable magnetic lens unit resting on said surface in sealing engagement with said sealing ring, a plurality of columns extending upwardly from said surface, a stage plate carried by said columns and extending parallel to said surface, said stage plate being positioned clear of the upper surface of the magnetic lens, a filler member having a tubular portion and a radially flanged portion, said radially flanged portion having a recess on its under face, a sealing ring in said recess, said sealing ring seating against the upper surface of the magnetic lens, and a closed top chamber member supported by said stage plate, said work chamber including a cover member having a recess on its under surface, a sealing ring accommodated in said recess, said sealing ring seating against a peripheral wall portion of said work chamber, and a removable window fitted to said work chamber.

6. An electron beam device as claimed in claim 5, comprising additional stage plates interposed between the magnetic lens and the work chamber, all said stage plates being arranged parallel one to the other and each being supported from the stage plate beneath it by means of spacer columns and additional components resting on said additional stage plates, said components being selected from magnetic lenses and intermediate chambers to form a complete assembly of components supported one over the other with the weight of the components transmitted to the gun structure at the bottom through the spacer columns whereby a magneic lens rests freely on the plate receiving it and is adapted for translation adjustment while the column is evacuated.

7. An electron beam device according to claim 6, comprising screw adjustment means on the columns adapted to impart lateral translation movement to a magnetic lens.

8. Electron beams equipment comprising a plurality of units which are designed to be assembled and disassembled from a limited number of units arranged to be coupled to form a rigid assemblage including means forming an evacuable space providing an electron path, an element towards which electrons are directed, said units including an electron gun unit at one end of the assemblage and a terminal chamber unit at the other end of said assemblage, at least one intermediate unit disposed between said electron gun unit and said terminal unit and in disconnectable vacuum-tight sealing contact between said electron gun unit and said terminal unit, said intermediate unit including a lens structure adapted to exert a focusing effect on electrons emitted from said gun and passing towards the terminal component.

9. Electron beam equipment as claimed in claim 8, including means for shifting said structure laterally relative to the assemblage for correction of the focusing action exerted by said structure.

10. Electron beam equipment according to claim 9, wherein a stage plate is provided with an O-ring sealing element against which a component placed thereon is seated and further including low-friction elements in the surface of the stage plate to support said lens structure in sealing contact with the sealing ring while permitting lateral adjustment displacement of said unit.

11. Electron beam equipment comprising a plurality of components which are designed to be assembled and disassembled from a limited number of mating components to form a rigid assemblage including an element towards which electrons are directed, said components including an electron gun unit at one end of the assemblage and a terminal close-ended chamber at the other end of said assemblage, a stage plate disposed transversely to the path of the electrons emitted by said gun, said stage plate forming part of said electron gun unit, further stage plates arranged parallel to and spaced from the said stage plate and forming part of said terminal chamber, an intermediate unit formed in part by said further stage plates, means interconnecting said stage plates to form a rigid assemblage, a magnetic lens structure disposed between adjacent pairs of said stage plates, vacuum sealing means disposed between said magnetic lens structure and said stage plates, and means associated with said interconnecting means for imparting a lateral adjustment movement to said magnetic lens structure relative to the assemblage for adjustment of the focusing action on said electron beam.

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