

May 6, 1947.

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2,420,077

DIRECT READING SPECTROCHEMICAL ANALYSIS APPARATUS

Filed Jan. 24, 1944

6 Sheets-Sheet 1

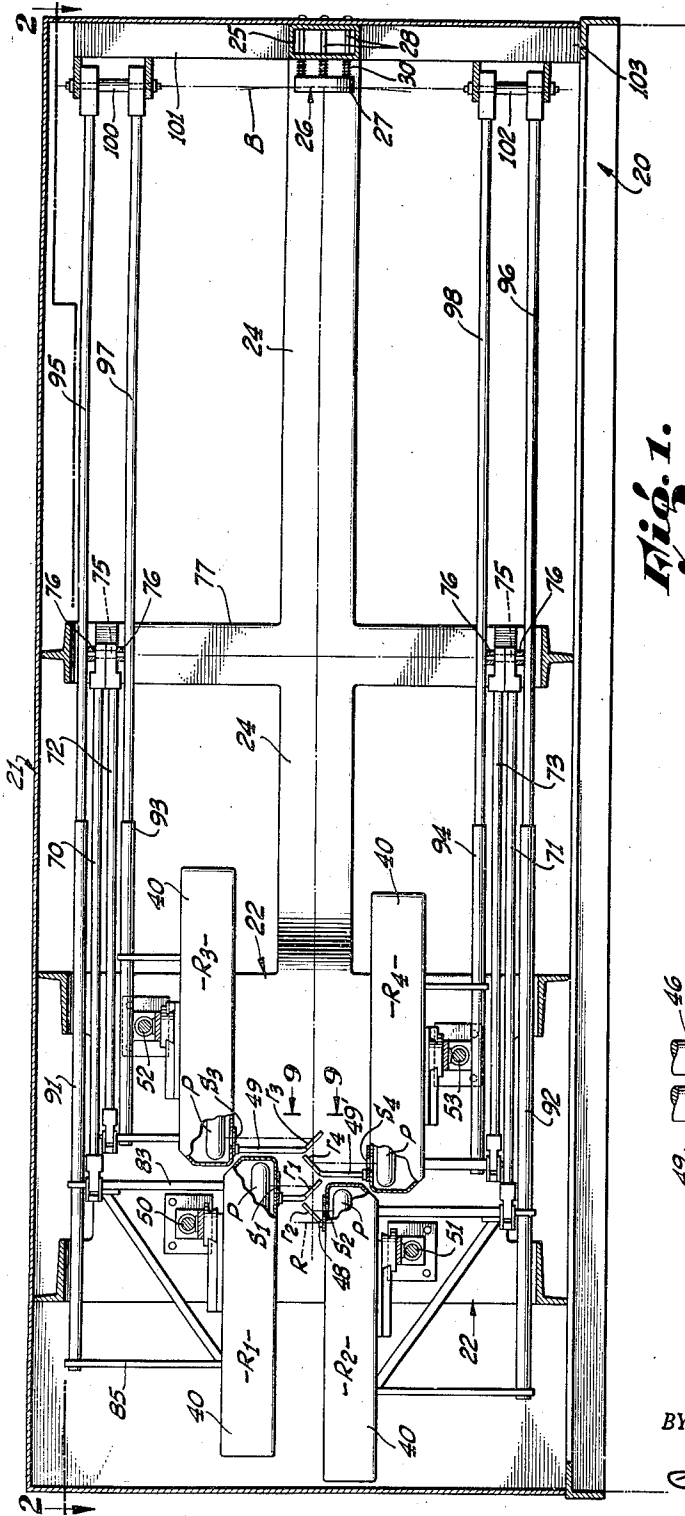


Fig. 1.

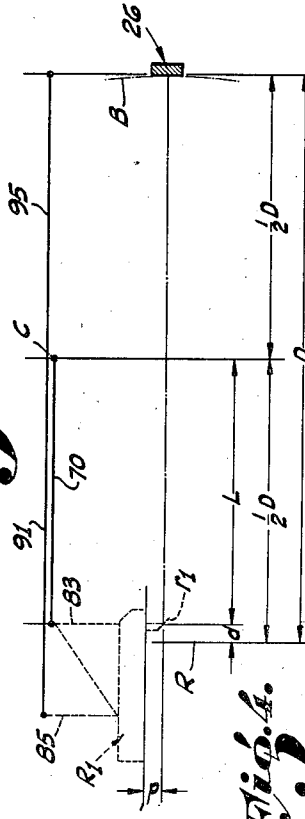


Fig. 4.

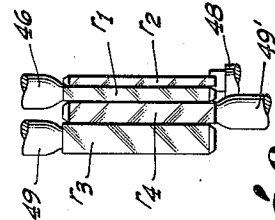


Fig. 9.

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6 Sheets-Sheet 2

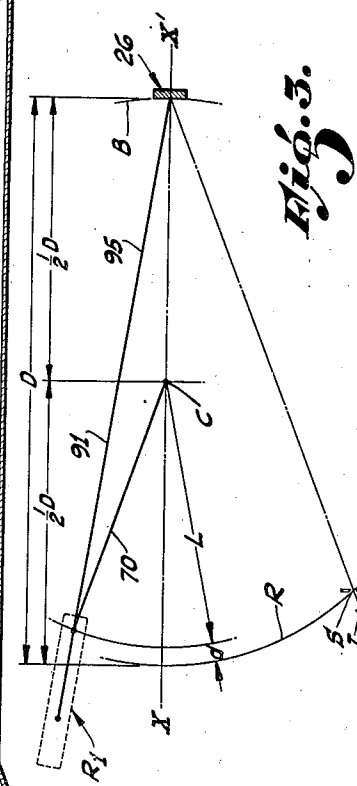
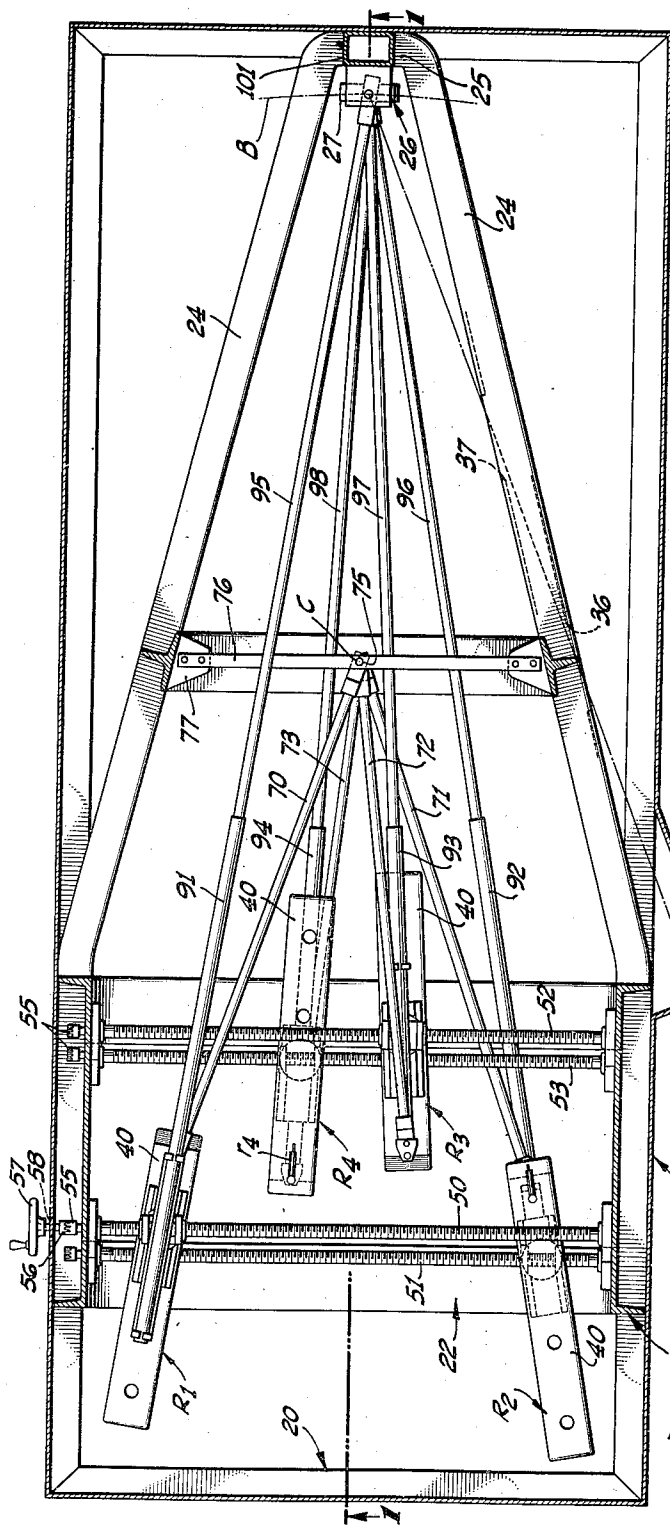


Fig. 2.

Fig. 3.

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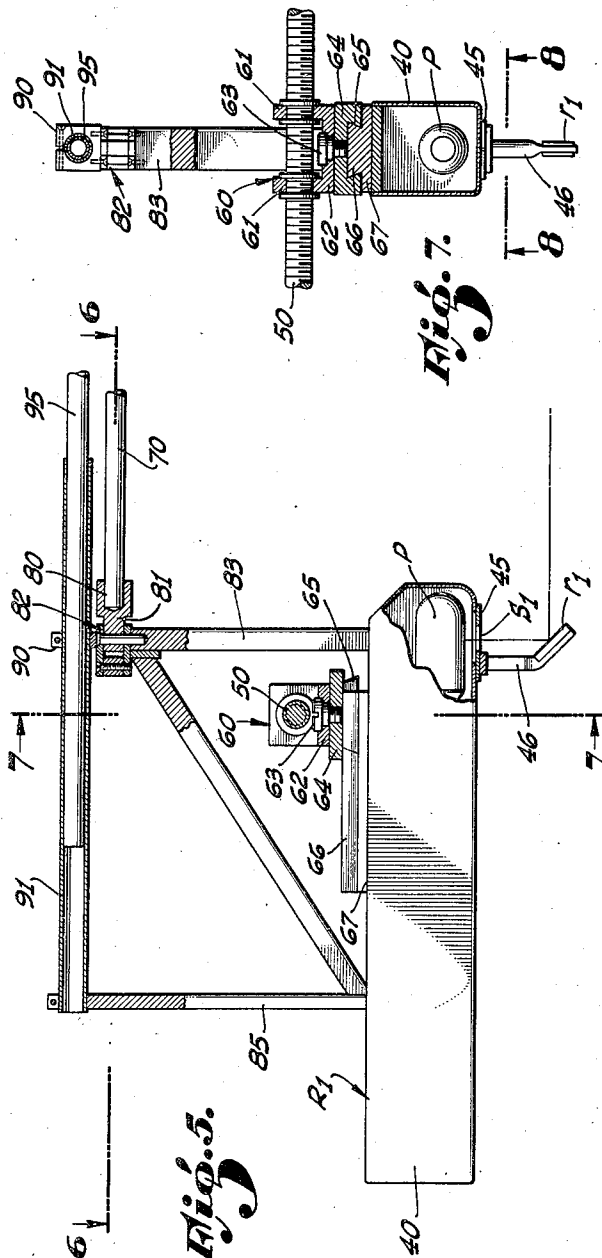
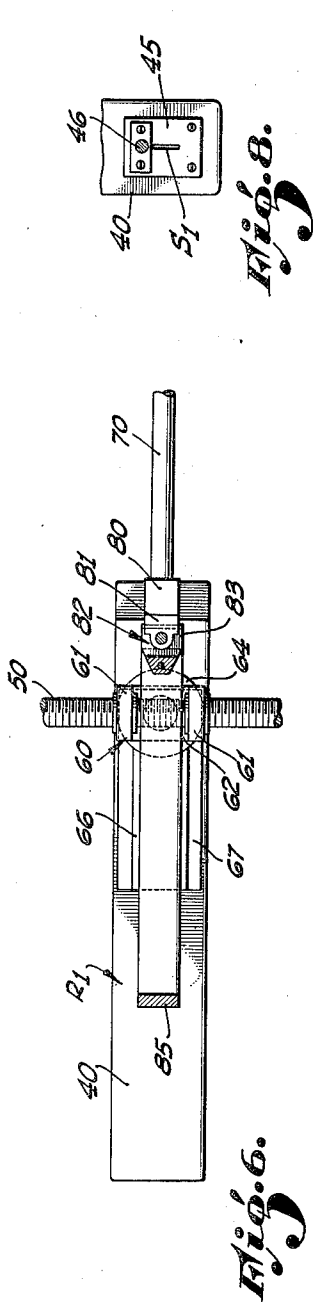


Fig. 5.

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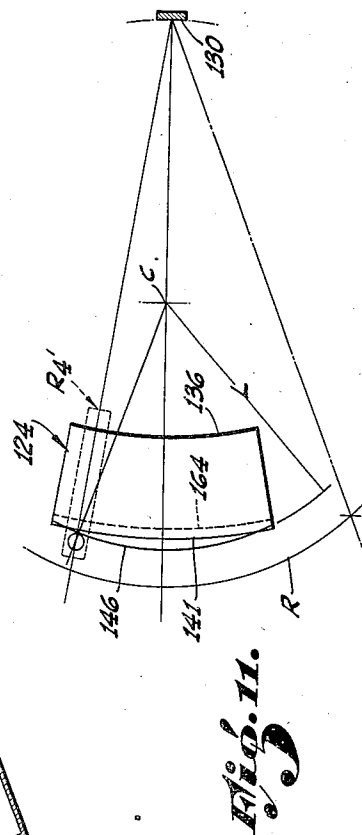
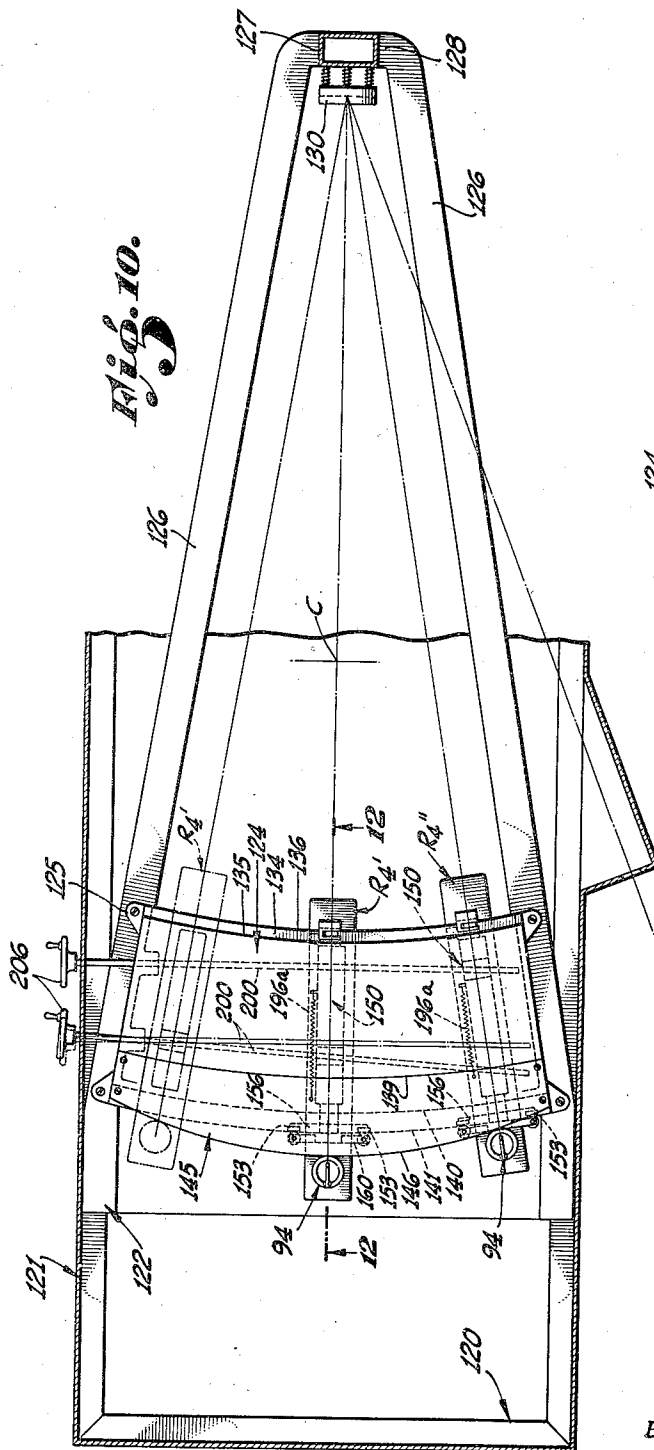
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DIRECT READING SPECTROCHEMICAL ANALYSIS APPARATUS

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Fig. 12.

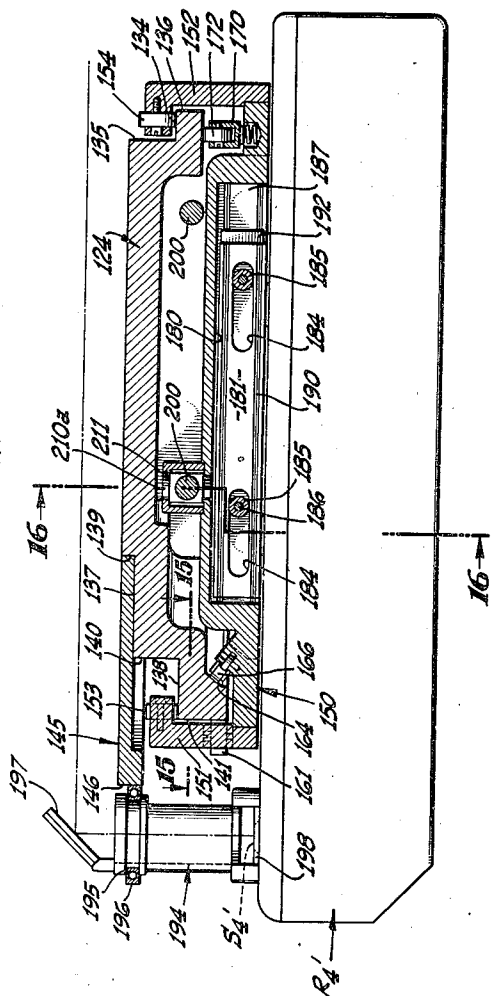
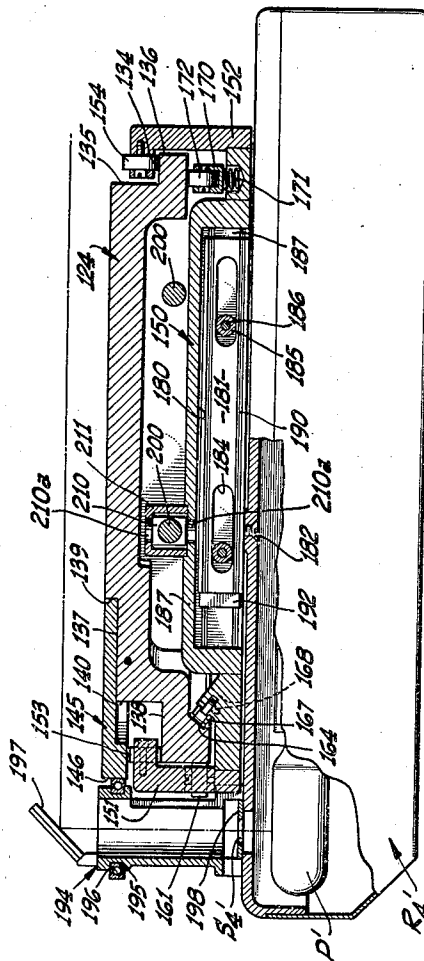


Fig. 13.



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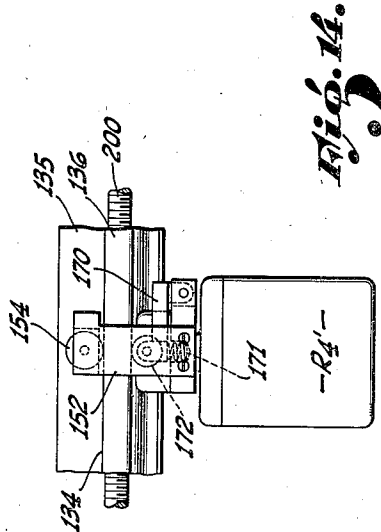
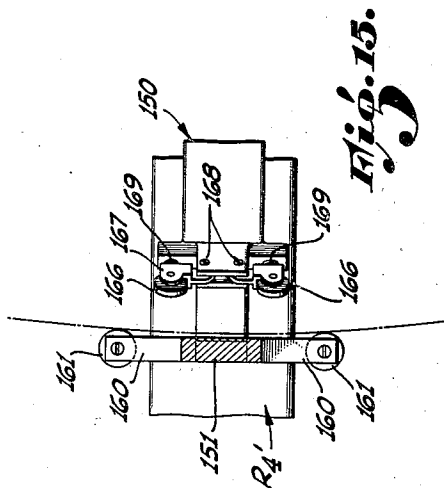
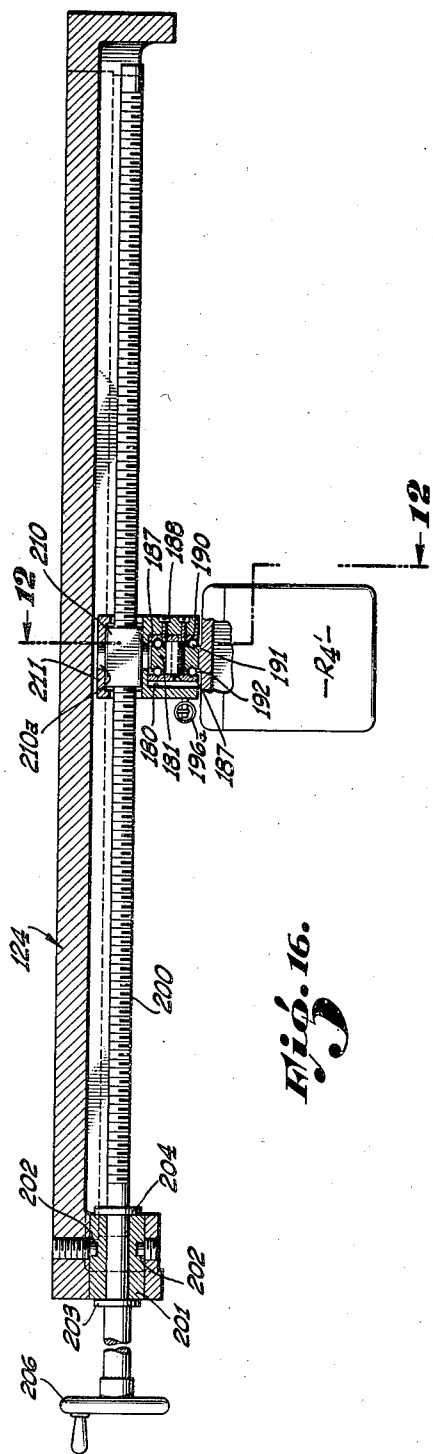
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DIRECT READING SPECTROCHEMICAL ANALYSIS APPARATUS

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UNITED STATES PATENT OFFICE

2,420,077

DIRECT READING SPECTROCHEMICAL
ANALYSIS APPARATUSMaurice F. Hasler and Roland W. Lindhurst,
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Application January 24, 1944, Serial No. 519,578

13 Claims. (Cl. 250—41.5)

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This invention relates generally to the art of spectrochemical analysis, and deals more particularly with direct reading spectrochemical analysis apparatus.

There has been a recent trend in the art of spectrochemical analysis toward the development of direct reading apparatus. Several obstacles have, however, been encountered, among which is the space requirement of direct reading receiver units with respect to the spectrum. Assuming a conventional multiplier phototube having a dimension of 31 mm. in diameter, and assuming further a usual spectrum, of a width of the order of an inch, and of constant dispersion, 7 Å. per mm., such as is produced by conventional gratings in previously known spectrographs, it is apparent that at least 220 Å. of the spectrum will be covered up if the phototube is placed directly in the spectrum beam, and also that the spectrum lines will be shorter than the phototubes. Besides the phototube, room for a surrounding case must be provided, so that the practical minimum length of the spectrum covered by a phototube becomes about 400 Å. With a spectrograph covering 2220 Å., this would allow five phototube receivers. Unfortunately, however, the lines of the various elements to be determined will not in general be 400 Å. apart and distributed uniformly throughout the spectrum.

An object of the invention is accordingly the provision of a plurality of phototube receivers which may be grouped in such a way as to permit simultaneous reading of lines which are much closer than 400 Å. apart, as for instance of the general order of from 14 to 30 Å. apart.

In accordance with the present preferred form of the invention, the spectrum lines are reflected into the receivers by narrow mirrors placed ahead of the focal plane, and the individual receivers of the group are arranged to clear one another as they are moved along the focal plane. Thus, the mirrors of the respective receivers may be moved into close juxtaposition with respect to the spectrum, whereby closely spaced lines may be read. The mirrors are not, however, positioned at equal distances from the grating, so that they as well as the receivers can actually pass one another.

A further object of the invention is the provision of automatic means for maintaining the re-

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ceivers trained on the grating and also maintaining the slits used before the phototubes thereof in the reflected focal plane of the spectrum during adjustment of the receivers into coincidence with spectrum lines of interest.

Other objects, features, aspects and accomplishments of the invention, not mentioned in the foregoing, will appear and be described in the course of the following detailed description of several preferred illustrative embodiments thereof, reference being had to the accompanying drawings, in which

Fig. 1 is a vertical longitudinal section of one embodiment of our spectrochemical analysis apparatus, taken approximately on line 1—1 of Fig. 2 but with the receiver units in a position in back of the cutting plane;

Fig. 2 is a horizontal section taken on line 2—2 of Fig. 1;

Fig. 3 is a diagram illustrating certain relationships incorporated in the invention;

Fig. 4 is a further diagram illustrating relationships incorporated in the invention;

Fig. 5 is a side elevation, with parts broken away, of one of the receiver units seen in Fig. 1;

Fig. 6 is a section taken on line 6—6 of Fig. 5;

Fig. 7 is a section taken on line 7—7 of Fig. 5;

Fig. 8 is a section taken on line 8—8 of Fig. 7;

Fig. 9 is a view taken in accordance with arrows 9—9 of Fig. 1, and showing the mirrors of the several receivers in juxtaposition to one another;

Fig. 10 is a plan view, with the enclosing housing partially indicated in section, of a modified embodiment of the invention;

Fig. 11 is a diagram illustrating certain relationships incorporated in the embodiment of Fig. 10;

Fig. 12 is a section taken approximately on line 12—12 of Fig. 10, and more particularly, on broken line 12—12 of Fig. 16.

Fig. 13 is a view similar to Fig. 12, but with certain additional parts sectionalized, and showing the receiver in a different position of operation;

Fig. 14 is an elevation looking at the right-hand end of the part seen in Fig. 12;

Fig. 15 is a detailed section taken in accordance with line 15—15 of Fig. 12; and

Fig. 16 is a section taken in accordance with broken line 16—16 of Fig. 12.

Referring first to the illustrative embodiment of the invention disclosed in Figs. 1-9, numeral 20 designates generally the rectangular top frame of a suitable supporting stand, the remainder of which need not be illustrated. Supported by this top frame 20 is a rectangular sheet metal casing 21 within which the spectrochemical analysis apparatus is housed. This apparatus, in its illustrative make-up, includes a box frame 22, of channel section, supported on stand 20 near one end thereof and extending entirely across and from top to bottom of casing 21. Reaching forwardly from the two sides of frame 22 are extensions 24 which converge towards one another and are joined, at the rearward end of the casing, by a cross frame portion 25. The frame members 24 and 25 may preferably be of rectangular box section, as appears in Fig. 1.

Carried by the cross frame portion 25 at the rearward end of the casing is the light dispersion element, usually and preferably, though not necessarily, a diffraction grating 26. This diffraction grating may be of any suitable or conventional design and its details need not be discussed herein. It will be understood, however, that it will embody a ruled reflective spherical (concave) face coinciding with an arc B whose radius of curvature is D (Fig. 3). The grating may as usual be enclosed within a suitable casing 27, here shown as carried by a plurality of adjustment screws 28 extending through the rearward wall of the housing 21 and the box frame 25. The screws will be understood to thread into the rearward wall of the casing 27, and coil springs 30 placed around said screws between frame 25 and the casing urge the latter in a direction away from the frame 25 and so maintain the grating in a position accurately predetermined by the setting of the screws.

It is well understood in the art that if the spectroscopic light source is located on the arc of a circle whose center is at a point C located $\frac{1}{2}$ D from the grating and on the normal to the grating surface, then the focal plane of the spectrum will coincide with an arc of that same circle. This circle is known as the Rowland circle, after the discoverer of the relationship. Accordingly, as appears in Fig. 3, the light source, in this instance a slit S, which may be illuminated by a spark or arc I, is located on the Rowland circle R, to one side of the central longitudinal axis X—X' of the apparatus. The spectrum will then be formed in a focal plane coinciding with an arc of this circle R. As appears in Fig. 2, the source I and the slit S are located outside one side wall of casing 21, opposite a suitable window 34 formed in a lateral extension 35 of the casing. In order to permit the slit S to be viewed from the position of the grating, apertures 36 and 37 are formed in the sides of the frame member 24 on the side corresponding with the slit, as clearly indicated in Fig. 2. It will, of course, be understood that the slit S and source I may be incorporated in a unit entirely separate of the apparatus contained within the casing 21, and since these elements may be of any desired type, they are merely diagrammatically indicated herein.

A plurality of direct reading receivers, preferably of a phototube, or multiplier phototube type, are mounted within casing 21 in the region of the arc of the Rowland circle R along which the spectrum will be cast by grating 26. In accord-

ance with the invention, the receivers may be arranged in one or more groups, there being typically and preferably, though not necessarily, four receivers in a group, arranged as presently to be described. For simplicity of illustration, but one such group is shown herein, and the addition of further groups, while ordinarily desirable, will be entirely obvious from the present disclosure.

In accordance with the illustrative embodiment disclosed in Figs. 1 through 9, a receiver group comprises four individual and individually adjustable receivers R₁, R₂, R₃ and R₄. Each of these is contained within an elongated casing 40, containing near one end photoelectric means in the form of a photoelectric tube or multiplier phototube P (see Fig. 5). The casing may also contain electrical circuiting and equipment associated with the phototube P. This equipment may be of any conventional or desired type capable of bringing the light intensity received at the phototube to an indication. Since such circuits are known, and since the circuit forms no part of the present invention, there is no necessity herein for the disclosure of an illustrative circuit.

Each receiver carries a narrow reflector which intersects a segment of the spectrum at a point in advance of the Rowland circle R (natural focal plane) and reflects it to a receiver slit in a new or "reflected" focal plane just in front of the phototube carried by the receiver. Fig. 4 indicates the method, where receiver R₁, positioned at a level above the grating, carries below it a 45° reflector r₁ located a distance d forwardly of the Rowland circle, the diameter of which is D. The mirror is located a distance L from the center of circle R, where

$$L = \frac{D}{2} - d$$

The reflector r₁ reflects the intercepted segment of the spectrum to a slit S₁ located at the bottom of the receiver, and spaced from mirror r₁ by a distance d', which is equal to the distance d, so that the segment of the spectrum intercepted by the mirror is imaged at the slit S₁. The light from this slit affects the phototube P directly above.

As indicated in Fig. 1, the four receivers R₁ to R₄ are all arranged to have their phototube-containing end portions in the general region just inside the Rowland circle R. The receivers R₁ and R₂ are respectively above and below the level of the grating, and are oppositely positioned to the receivers R₃ and R₄, which latter are likewise above and below, respectively, the level of the grating. That is to say, the receivers R₁ and R₂ extend from their phototube ends in a direction away from the grating, while the receivers R₃ and R₄ extend from their phototube ends in a direction toward the grating.

Considering particularly the receiver R₁, and with reference to Fig. 5, the casing 40 for the receiver R₁ has, just below the phototube P, a plate 45 having the slit S₁. Directly below this slit, and at the horizontal level of the grating, is the narrow 45° reflector r₁ carried by a suitable bracket 46 hung from the underside of the receiver casing. As previously explained, the distance from this reflector to the slit S₁ is equal to the distance from the reflector to the focal plane circle R.

The receiver R₂, which is a little further removed from the grating than receiver R₁, carries its reflector r₂ above, being provided with any

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suitable reflector mounting 48 on the top side of its casing. Like reflector r_1 , this reflector r_2 is located at the horizontal level of the grating, and it is positioned between reflector r_1 and focal plane R, with the distance from reflector r_2 to focal plane R equal to the distance from said reflector r_2 to the slit S₂. It will be noted that the receiver R₂ has been placed closer to the horizontal plane of the grating and a little back from receiver R₁ in order to accomplish the described relationship.

Receiver R₃ is positioned a little in advance of R₄. These receivers carry their respective reflectors r_3 and r_4 at the level of the grating by means of brackets 49 and 49', respectively, with reflector r_3 just forwardly of reflector r_4 , and the latter just forwardly of reflector r_1 , all as clearly appears in Fig. 1. Further, the receivers R₃ and R₄ are located at such horizontal levels that their respective photo cell slits S₃ and S₄ will be spaced from the respective reflectors by distances equal to the distances between said reflectors and the focal plane circle R.

The reflectors r_1 to r_4 thus intercept segments of the spectrum and provide reflected focal planes at the locations of the respective receiver slits S₁ to S₄. These reflectors are made relatively narrow, being no wider than is necessary to form satisfactory line images at the slits. The reflectors r_2 , r_1 , r_4 and r_3 , being at progressively increasing distances from the slits, should be of progressively increasing widths for maximum illumination. In a present embodiment, the four reflectors are 1.6, 2.4, 3.6 and 4.8 mm. wide, respectively, which may be taken as typical. When the four receivers are so positioned (through means presently to be described) that these reflectors are all next to one another (Fig. 9) spectrum lines as close together as 14 Å., 21 Å., and 30 Å. can be used simultaneously.

The receivers R₁, R₂, etc., are supported for individual movement along the arc of the focal plane circle R, and means are provided for maintaining them always directed toward the grating, as well as for maintaining the slits of the receivers always in their respective "reflected" focal planes. While various means may be provided for accomplishing these purposes, one illustrative embodiment is shown in Figs. 1 through 9 and will be described in detail. Four horizontal lead screws 50, 51, 52 and 53 extending transversely of the frame 22 are provided, one for each of the receivers. These extend between the two sides of the frame 22, the lead screws 50 and 52 for the upper receivers R₁ and R₃ being located above the respective receivers, and those for the lower receivers R₂ and R₄ being located below the latter, as clearly appears in Fig. 1. These lead screws are journaled in suitable bearings carried by the sides of the frame 22, and are provided at one end with extensions having clutch heads 55 engageable by a mating clutch head 56 carried by a hand wheel 57 projectable through suitable apertures 58 in the side of the casing. Each of the lead screws operates its respective receiver through means best seen in Figs. 5, 6 and 7. While Figs. 5, 6 and 7 show only the receiver R₁, it will be understood that the operative connections between the other lead screws and their respective receivers are similar, excepting only for an inverted position in the cases of R₂ and R₄. A U-shaped bracket 60 has two parallel sides 61 threadedly mounted on the lead screw, and a base 62. Pivottally connected to this base by means of a headed screw 63 is a plate 64 formed

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in the bottom with a dovetail way 65, and slidably received in the latter is the dovetail projection 66 of a mounting plate 67 secured to the receiver.

Rotation of the lead screw will thus effect movement of the receiver transversely of the casing 21. The receiver is free, however, for longitudinal as well as pivotal movement relative to the mounting bracket 60 which rides on the lead screw.

The four receivers R₁, R₂, R₃ and R₄ are in the present instance maintained with their respective slits in the reflected focal planes during adjustment by the lead screws by means of four links 70, 71, 72 and 73, respectively, which are pivoted at one end on a common vertical pivot axis coinciding with the center C of the Rowland circle. In the arrangement here shown, the links 70 and 72 are arranged in the upper portion of the apparatus, with the link 70 above the link 72, and both pivottally mounted on a pivot pin 75 carried by transverse supporting bars 76 mounted at their ends on frame members 77. Similarly, the links 71 and 73 are arranged in the lower portion of the apparatus, with link 73 over link 71, and both pivottally mounted on a pivot pin 75 carried by frame bars 76 similar to those just above described.

Figs. 5-7 show a typical interconnection between a constraining link and its respective receiver, in this instance between the link 70 and the receiver R₁. The swinging end of the link 70 is received in the socket 80 of a connection member 81 which is pivottally connected, by means of a knuckle joint 82, with the upper end of a supporting arm 83 that extends upwardly from the receiver casing, the vertical pivot axis of the knuckle joint coinciding with the center of the slit S₁.

Also carried by arm 83, above knuckle joint 82, is a fixed clamp support 90 for a guide tube 91 which extends parallel to the receiver casing, and the rearward end of which is clamped and supported by the upper end of a rearward supporting arm 85. Similar tubes 92, 93 and 94 are associated in a generally similar manner with the receivers R₂, R₃ and R₄, respectively, though in the present instance the tubes 93 and 94 are located between the respective links 72 and 73 and the receivers, rather than outside said links. In all cases, however, these tubes 91 to 94 are fixed in parallel relationship to the respective receivers. Telescopically received in the tubes 91, 92, 93 and 94 are tubes 95, 96, 97 and 98, respectively, which have pivotal mountings at the grating end of the apparatus, on a common vertical pivot axis coinciding with the curved face of the grating.

As shown, the ends of the upper tubes 95 and 97 are mounted on a pivot pin 100 carried by bracket arms projecting from the upper end of a vertical frame extension 101, while the lower tubes 96 and 98 are mounted on a similar pivot pin 102 carried by bracket arms projecting from a vertical frame extension 103.

As the lead screws 50, 51, 52 or 53 are rotated, the corresponding receivers are moved transversely across the casing. Because of the telescoping tubes interconnecting the receiver casings with the vertical pivot axis coinciding with the center of the face of the grating, the receivers are constrained to maintain their radial alignment with the grating in the course of such adjustment movement. They are permitted the necessary swinging movement relative to the lead screws by virtue of the pivotal connection 63 be-

tween the lead screw mounting bracket 60 and the receiver casing.

Because of the constraint provided by the links 70 to 73, the receiver slits are always maintained in their respective reflected focal planes, and the longitudinal movements of the receivers necessary to accomplish this are permitted by the sliding connections provided between the dovetailed elements 65 and 66 (Figs. 5-7).

It will be evident from what has been said, and from a consideration of Fig. 1, that the individual receivers of the illustrated group, and the respective reflectors carried thereby, are out of alignment with one another as regards movement along the focal plane arc; in other language, they occupy nonoverlapping positions as viewed in planes transverse of the spectrum, or radial of the curved focal plane of the spectrum and of the curved grating. Hence, they may pass one another in adjustment along said arc, or be placed in any desired degree of proximity to one another. Thus the receivers may not only be passed entirely by one another, but may be adjusted to position their respective mirrors immediately adjacent one another as viewed from the grating (Fig. 9), so that relatively close spectrum lines may be simultaneously received and measured.

In Figs. 10 to 16 we have illustrated a modified type of means for adjusting the receivers along the focal plane circle, and for maintaining them both directed toward the grating and positioned with their slits on the reflected focal plane circle. In disclosing the first embodiment of the invention, we illustrated one representative group of four receivers, the individual members of which were capable of passing one another, and mentioned that by mere duplication or repetition, other similar groups might be added alongside the first group. To avoid confusion of illustration and description, Figs. 10 to 16 are confined to a single representative receiver of each of two such groups. The two illustrated receivers of the two groups, which receivers are designated by numerals R_4' and R_4'' , respectively, because they correspond generally with the receiver R_4 of the first described embodiment, are disposed at the same horizontal level, and of course are not intended to pass one another. They may approach one another only as closely as the widths of their casings will permit. It will readily be understood by those skilled in the art that additional receivers may be added to each of the two receiver groups represented by the illustrated receivers R_4' and R_4'' , and that the individual members of each group will be arranged to pass one another in the general manner indicated in connection with Figs. 1 to 9.

Referring now to Figs. 10 to 16, and particularly to Fig. 10, numeral 120 designates generally a fragmentary portion of a rectangular top frame of a suitable supporting stand, on which is carried rectangular sheet metal casing 121, only fragmentarily indicated in the figure. Supported on the stand 120 in any suitable fashion is a frame casting 122 on which is mounted, near one end of the apparatus, a generally arcuate shaped guide table 124. As here shown, this guide table 124 is furnished with ears 125 resting on and secured to frame members 126, which converge toward the other end of the apparatus and are joined by a cross-frame portion 127, from which extends a vertical member 128 carrying the diffraction grating 130, shown as provided with a mounting similar to that illustrated in Fig. 1.

The edge of the table 124 nearest the grating is

provided with a ledge or step 134, and with upper and lower arcuate edge portions 135 and 136, which have their centers at the center of the grating 130. The forward edge of table 124, that most remote from the grating, is provided with two horizontal steps or ledges 137 and 138, which are defined by three vertical edge portions 139, 140 and 141 of arcuate contour, having their centers at the center of the grating 130. Resting on the step 137 and against edge 139 is a guide plate 145 having an arcuate edge 146 of radius L (Fig. 11), whose center of curvature is located at the center C of the Rowland circle (Figs. 10 and 11). The plate 145 is united to the table 124 and forms in effect a portion thereof.

Hung below and guided by the guide table 124 is a carriage 150 for the receiver (see Figs. 12 to 15). This carriage 150 includes two end hangers or brackets 151 and 152 which extend past the forward and rearward arcuate edge portions 141 and 136, respectively, of table 124 and carry rollers 153 and 154, respectively, which bear against the respective steps 138 and 134. As shown best in Fig. 10, there are two of the rollers 153, carried by extension arms 156, while, as appears in Fig. 14, there is but a single roller 154 carried by the bracket 152.

Two lateral extensions 160 from bracket 151 carry rollers 161 adapted to bear and run on the arcuate edge surface 141 of the guide table, which thus serves as a track.

The underside of guide table 124 is transversely channelled to accommodate certain later described parts, and this channel is defined at the front of the table by an arcuate surface or track 164, understood to be concentric with the track 141, i. e., having its center of curvature at the center of the grating. The tracks 141 and 164 face in opposite directions, but the track 164 preferably, and as here shown, is disposed at an angle of 45° to vertical as viewed in vertical cross-section (Figs. 12 and 13). Engaging this track 164 are a pair of angularly mounted spring-urged rollers 166 carried by carriage 150. These rollers 166 are here shown as supported by carriers 167 (Fig. 15) pivotally mounted at 168 on the carriage 150 and spring-urged to maintain the rollers tight against the track by coil springs 169. The rollers 166 thus cooperate with both the rollers 153 and the rollers 161 in positioning the forward end portion of the carriage with respect to the arcuate tracks of the guide table, functioning to maintain not only a predetermined relative horizontal position, but a predetermined relative vertical position as well.

At the rearward end of the carriage is a pivotally mounted arm 170 (Fig. 14), pressed upwardly by a spring 171, and carrying a roller 172 which bears against a flat bearing surface on the underside of the table 124, thereby positioning the rearward portion of the carriage against vertical displacement with reference to the table.

Carriage 150 has a downwardly opening cavity 180 (Figs. 12, 13 and 16), in which is received a receiver supporting bar 181, to the bottom edge of which the receiver casing is secured, as by screws 182 (Fig. 13). This bar 181 has a pair of longitudinal guide slots 184, in which are received spacer sleeves 185 mounted on studs 186 extending between and carried by a pair of plates 187, which will be understood to extend substantially the length of the cavity 180, the bar 181 being somewhat shorter, so as to have some capability for longitudinal movement, as appears in

Figs. 12 and 13. One of the plates 187 is secured to the carriage by means of screws 188, while the other of said plates is carried by and spaced from the former by means of the previously described sleeve 185 and stud 186, all as will be clearly understood from Fig. 16. The opposing faces of the plates 187 and the bar 181 are formed with longitudinal horizontal raceways 190 for ball bearings 191, and a ball retainer plate 192, having suitable apertures to accommodate the ball bearings, is preferably employed between the bar 181 and each of the plates 187.

The receiver is thus suspended from carriage 150 for longitudinal movement relative to the latter by means of the bar 181 and the ball bearings placed between the latter and the plates 187 affixed to the carriage. The sleeves 186 preferably do not assume the weight of the receiver, and function simply as spacers.

Mounted on the forward end of the receiver casing is a hollow casting 194, the upper end of which carries a bearing comprising inner and outer race rings 195 and 196 and intervening bearing balls. The outer race ring 196 bears against the arcuate track 146 on the guide plate member 145, which track will be recalled as having a center of curvature coinciding with the center of the Rowland circle, rather than with the center of the grating. The receiver is maintained with its race ring 196 constantly bearing on the arcuate track 146 by any suitable means, preferably a spring, and such a spring is here shown at 196a, connected between the receiver casing and the side of carriage 150.

The open end of casting 194 carries narrow 45° reflector 197 at the level of the diffraction grating, and reflects the intercepted segment of the spectrum to a focus at slit S₄' formed in an aperture plate 198 at the top side of the receiver casing and just over the photocell P'. The reflector 197 will be understood to be located the same horizontal distance inside the Rowland circle R as it is located vertically above the slit S₄', so that the reflected focal plane will coincide with the slit.

It will be evident that the carriage 150, and the receiver carried thereby, may be moved along guide table 124, and that in such movement, the rollers of the carriage 150 will follow the arcuate tracks 141 and 164. And since these arcuate tracks have their centers of curvature at the center of the grating, the carriage, and therefore the receiver carried thereby, will be maintained in a radial position with respect to the grating throughout such movement.

The described movement of the carriage and receiver along the arcuate tracks 141 and 164 of the guide table will be accompanied by relative longitudinal movement of the receiver and carriage, owing to coaction between the roller or race ring 196 carried by the receiver and the arcuate track 146 whose center of curvature is at the center of the Rowland circle.

There remains for description only some suitable means for effecting the described movement of the receiver carriages along the arcuate tracks of the guide table, and one typical example of such means will now be described.

Lead screws 200, one for each receiver, are journaled in one end of the guide table. As best shown in Fig. 16, each of these lead screws is journaled in a bearing sleeve 201, which is vertically trunnioned at 202 in the edge portion of the table. Endwise movement of the lead screws is prevented by collars or flanges 203 and 204

mounted on the screws and engaging the ends of the sleeve 201, and the screws are rotated for adjustment purposes by hand wheels 206. These lead screws pass between the guide table 124 and the carriages 150, and are connected to the latter through nuts 210 mounted on the screws and provided with vertical trunnions 210a of which the upper ones are journaled in U-shaped housings 211 affixed to the tops of the respective carriages, and the lower ones are journaled directly in the tops of the carriages (Figs. 13 and 16). Rotation of one of the lead screws effects translation of the corresponding nut 210, and hence of the corresponding carriage. The vertical trunnion mounting of the lead screw bearing 201 permits angular swing of the lead screw, and the trunnion mounting of the nut 210 permits relative swinging movement of the screw and carriage.

We have now disclosed the present invention by way of a more or less detailed description and illustration of certain present preferred means for carrying the invention into practical effect. It will be understood, however, that this is for illustrative purposes only, and that various changes in design, structure and arrangement may be made without departing from the spirit and scope of the invention as defined in the appended claims.

We claim:

1. In a spectroscopic analysis apparatus including an optical element which directs a spectrum beam to a focus in an arcuate focal plane whose center of curvature is noncoincident with said optical element, a photoelectric spectrum line receiver, a receiver carriage, means including an arcuate track supporting and guiding said receiver carriage for adjustment movement along an arcuate path whose center of curvature is located at said optical element, whereby said receiver carriage maintains a predetermined radial alignment with said optical element, means supporting said receiver for relative movement on said receiver carriage in directions toward and from said optical element, and means including an arcuate receiver guiding track having its center of curvature located at the center of curvature of said arcuate focal plane operatively associated with said receiver to move said receiver relative to its carriage during said adjustment movement of said carriage along said arcuate path, in such manner as to maintain said receiver in a fixed relation to said focal plane throughout said adjustment movement.

2. In a spectroscopic analysis apparatus having an optical element adapted to produce a spectrum beam coming to a focus in an arcuate focal plane whose center of curvature is substantially half way between said element and said focal plane, a plurality of photoelectric spectrum line receivers adjacent said spectrum beam in the region of said spectrum and arranged to occupy nonoverlapping positions as viewed in planes which are radial with respect to said arcuate focal plane, means supporting and guiding said receivers for lateral adjustment movement along arcuate paths which are parallel to said arcuate focal plane, means constraining said receivers to maintain radial alignments with respect to said optical element throughout such lateral adjustment movement, relatively narrow reflectors, of widths narrower than the lateral widths of the receivers, carried by said receivers in positions of lateral alignment in the path of said spectrum beam and adapted to intercept segments there-

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of and reflect same to the receivers, said reflectors being located at different distances in front of said arcuate focal plane so as not to interfere with one another during lateral adjustment movement of the receivers, and the distances from the reflectors to their respective receivers being equal to the distances at which said respective reflectors are located in front of the said arcuate focal plane.

3. In a spectroscopic analysis apparatus including an optical element which directs a spectrum beam to a focus in an arcuate focal plane, whose center of curvature is located on the normal to said optical element but in a position spaced from the latter, a photoelectric spectrum line receiver in the region of said arcuate focal plane, a receiver carriage, means including an arcuate track supporting and guiding said receiver carriage for adjustment movement along an arcuate path whose center of curvature is located at said optical element, whereby said receiver carriage maintains a predetermined radial alignment with said optical element, means supporting said receiver for relative longitudinal movement on said receiver carriage, means for maintaining said receiver in a predetermined position relative to said arcuate focal plane including an arcuate receiver guiding track having its center of curvature located at the center of curvature of said arcuate focal plane, a hollow mounting on said receiver opposite said track, a guide roller carried by said mounting arranged to bear on said track, and a reflector carried by said receiver adapted and positioned to intercept a segment of said spectrum and to reflect it into said receiver through said hollow mounting.

4. In a spectroscopic analysis apparatus having a light source embodying a light slit and an optical projection system including light dispersing means adapted to receive light from said slit and to cast a spectrum beam forming a spectrum in a focal plane: a plurality of photoelectric spectrum line receivers adjacent said spectrum beam in the region of said spectrum, said receivers being movable in directions parallel to said spectrum, a corresponding plurality of spectrum beam reflectors of widths substantially less than the receiver widths carried by said receivers in said spectrum beam between said light dispersing means and said focal plane and in positions laterally aligned with one another as viewed from said light dispersing means but at different distances therefrom, said reflectors being angularly arranged with respect to and adapted to intercept segments of the spectrum beam and reflect same to the receivers, and said receivers and reflectors being offset from one another as viewed in planes at right angles to said spectrum and parallel to the lines thereof, all in such manner that said receivers and said reflectors may clear one another in said movement parallel to said spectrum, and whereby spectrum lines separated by lesser distances along the spectrum than the widths of said receivers may be simultaneously received.

5. In a spectroscopic analysis apparatus having a light source embodying a light slit and an optical projection system including light dispersing means adapted to receive light from said slit and to cast a spectrum beam forming a spectrum in a focal plane: a plurality of photoelectric spectrum line receivers adjacent said spectrum beam in the region of said spectrum, said receivers being movable in directions parallel to said spectrum, a corresponding plurality of spectrum beam

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reflectors of widths substantially less than the receiver widths carried by said receivers in said spectrum beam between said light dispersing means and said focal plane and in positions laterally aligned with one another as viewed from said light dispersing means but at different distances therefrom, said reflectors being angularly arranged with respect to and adapted to intercept segments of the spectrum beam and reflect same to the receivers, the light path distances from the reflectors to their respective receivers being equal to the distances by which the respective reflectors are located in front of said focal plane, and said receivers and reflectors being offset from one another as viewed in planes at right angles to said spectrum and parallel to the lines thereof, all in such manner that said receivers and said reflectors may clear one another in said movement parallel to said spectrum, and whereby spectrum lines separated by lesser distances along the spectrum than the widths of said receivers may be simultaneously received.

6. In a spectroscopic analysis apparatus having a light source embodying a light slit and an optical projection system including light dispersing means adapted to receive light from said slit and to cast a spectrum beam forming a spectrum in a focal plane: a group of four relatively elongated, photoelectric spectrum line receivers in the region of said spectrum, with one pair of said receivers on one side and another pair of said receivers on the opposite side of said spectrum beam, and with the two receivers of each of said pairs extending in opposite directions forwardly and rearwardly of the spectrum from a location forwardly of said spectrum, a corresponding plurality of spectrum beam reflectors of widths substantially less than the receiver widths carried by said receivers in said spectrum beam between said light dispersing means and said focal plane in positions laterally aligned with one another as viewed from said light dispersing means but at different distances therefrom, said receivers being individually so spaced from said spectrum beam that the light path distance from each reflector to its respective receiver is equal to the distance between that reflector and said focal plane, said receivers and reflectors being positioned and arranged to occupy non-overlapping positions as viewed in planes at right angles to said spectrum and parallel to the lines thereof, and means supporting said receivers for individual travel in directions parallel to one another and to said spectrum, all in such manner that said receivers and said reflectors may clear one another in said movement parallel to said spectrum, and whereby spectrum lines separated by lesser distances along the spectrum than the widths of said receivers may be simultaneously received.

7. In a spectroscopic analysis apparatus having a light source embodying a light slit and an optical projection system including light dispersing means adapted to receive light from said slit and to cast a spectrum beam forming a spectrum in a focal plane: a plurality of photoelectric spectrum line receivers adjacent said spectrum beam in the region of said spectrum, said receivers being movable in directions parallel to said spectrum, a corresponding plurality of spectrum beam reflectors of widths substantially less than the receiver widths positioned in said spectrum beam between said light dispersing means and said focal plane and in positions laterally aligned with one another as viewed from said light dispersing means but at different distances therefrom, said

reflectors being angularly arranged with respect to and adapted to intercept segments of the spectrum beam and reflect same to the receivers, said reflectors being movable in directions parallel to said spectrum with their respective receivers, and said reflectors and their corresponding reflectors being offset from one another as viewed in planes at right angles to said spectrum and parallel to the lines thereof, all in such manner that said receivers and said reflectors may clear one another in said movement parallel to said spectrum, and whereby spectrum lines separated by lesser distances along the spectrum than the widths of said receivers may be simultaneously received.

8. In a spectroscopic analysis apparatus having a light source embodying a light slit and an optical projection system including light dispersing means adapted to receive light from said slit and to cast a spectrum beam forming a spectrum in a focal plane: a plurality of photoelectric receivers adapted to receive simultaneously segments of said spectrum which are coextensive transversely of the spectrum but non-coextensive longitudinally thereof, said receivers being positioned in the region of said spectrum, reflector means associated with one of said receivers having a width substantially less than the receiver width and positioned in said spectrum beam forward of said focal plane, said reflector means being angularly arranged with respect to and adapted to intercept a segment of said spectrum beam and reflect same to the receiver, said receivers and reflector means being movable in directions parallel to each other and to the spectrum, and said receivers and reflector means being offset from one another as viewed in planes at right angles to said spectrum and parallel to the lines thereof, all in such manner that said receivers and said reflector means may clear one another in said movement parallel to said spectrum, and whereby spectrum lines separated by lesser distances along the spectrum than the widths of said receivers may be simultaneously received.

9. In a spectroscopic analysis apparatus including an optical element which directs a spectrum beam to a focus in an arcuate focal plane whose center of curvature is non-coincident with said optical element, a photoelectric spectrum line receiver, a receiver carriage, means supporting and guiding said receiver carriage for movement along an arcuate path whose center of curvature is located at said optical element, whereby said receiver carriage maintains a predetermined radial alinement with said optical element, means supporting said receiver for relative movement on said receiver carriage in directions toward and from said optical element, and means including an arcuate receiver guiding track having its center of curvature located at the center of curvature of said arcuate focal plane operatively associated with said receiver to move said receiver relative to its carriage during said movement of said carriage along said arcuate path, in such manner as to maintain said receiver in a fixed relation to said focal plane throughout said movement along said arcuate path.

10. In a spectroscopic analysis apparatus including an optical element which directs a spectrum beam to a focus in an arcuate focal plane whose center of curvature is non-coincident with said optical element, a photoelectric spectrum line receiver, a guide means having two arcuate track surfaces, one having its center of curvature at

said optical element, and the other having its center of curvature in coincidence with the center of curvature of said arcuate focal plane, a receiver carriage, roller means on said receiver carriage bearing on said one arcuate track surface, said receiver mounted on said carriage for relative movement at right angles to said one arcuate track surface, and roller means carried by said receiver bearing on said other arcuate track surface.

11. In a spectroscopic analysis apparatus including an optical element which directs a spectrum beam to a focus in an arcuate focal plane whose center of curvature is non-coincident with said optical element, a photoelectric spectrum line receiver, a guide table parallel to said spectrum beam, said guide table having two arcuate edge tracks, one having its center of curvature at said optical element, and the other having its center of curvature in coincidence with the center of curvature of said arcuate focal plane, a receiver carriage positioned at one side of said guide table, roller means on said carriage engaging said one arcuate edge track, flat bearing surfaces on both sides of said guide table, roller means on said carriage engaging said bearing surfaces, an arcuate bearing surface on said guide table parallel to said one track edge but facing oppositely therefrom, roller means on said carriage engaging said last-mentioned arcuate bearing surface, said receiver mounted on said carriage for relative movement at right angles to said one arcuate track surface, and roller means carried by said receiver bearing on said other arcuate track surface.

12. In a spectroscopic analysis apparatus including an optical element which directs a spectrum beam to a focus in an arcuate focal plane whose center of curvature is non-coincident with said optical element, a photoelectric spectrum line receiver, a guide means having two arcuate track surfaces, one having its center of curvature at said optical element, and the other having its center of curvature in coincidence with the center of curvature of said arcuate focal plane, a receiver carriage, roller means on said receiver carriage bearing on said one arcuate track surface, said receiver mounted on said carriage for relative movement at right angles to said one arcuate track surface, roller means carried by said receiver bearing on said other arcuate track surface, and means for moving said receiver and carriage along said track surfaces embodying a pivotally mounted lead screw, and a nut on said lead screw pivotally connected to said receiver carriage.

13. In a spectroscopic analysis apparatus including an optical element which directs a spectrum beam to a focus in an arcuate focal plane whose center of curvature is non-coincident with said optical element, a photoelectric spectrum line receiver, a receiver carriage, means supporting and guiding said receiver carriage for movement along an arcuate path whose center of curvature is located at said optical element, whereby said receiver carriage maintains a predetermined radial alinement with said optical element, means supporting said receiver for relative movement on said receiver carriage in directions toward and from said optical element, means including an arcuate receiver guiding track having its center of curvature located at the center of curvature of said arcuate focal plane operatively associated with said receiver to move said receiver relative to its carriage during said move-

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ment of said carriage along said arcuate path, in such manner as to maintain said receiver in a fixed relation to said focal plane throughout said movement, and means for moving said receiver along said arcuate path embodying a pivotally mounted lead screw, and a nut on said lead screw pivotally connected to said receiver carriage.

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