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[33] **Sweden**
[31] **11,530 and 11,531**

[54] **STRUCTURE FOR CONE AND PERISCOPE OF SPIRAL PATH SCANNING MECHANISM**
9 Claims, 6 Drawing Figs.

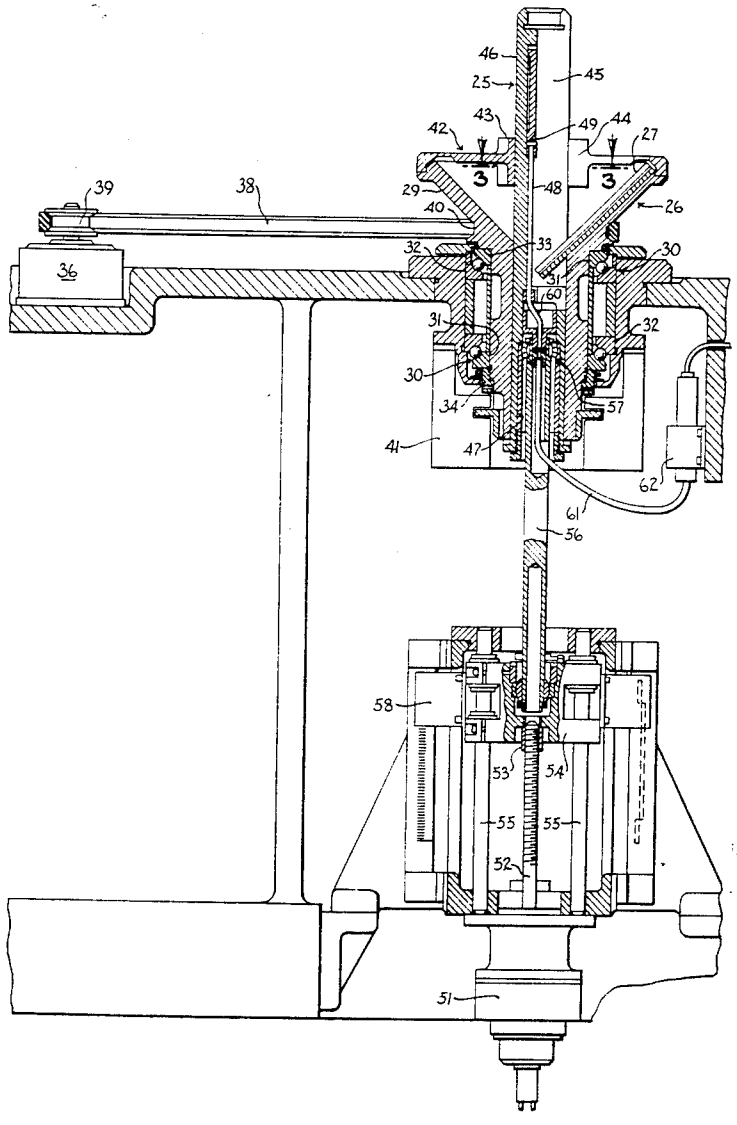
[52] **U.S. Cl.** **350/6,** 178/7.6, 250/236, 350/7, 350/285
[51] **Int. Cl.** **G02b 17/00**
[50] **Field of Search** ..... 350/6, 7, 22, 285, 52; 250/81—85, 235—237; 178/7.6; 74/84 (C)

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ABSTRACT: A scanner for bubble chamber photographs comprises a rotatable mirror-carrying outer member and an inner periscope member that rotates with and moves lengthwise relative to the outer member. The periscope member has accurately straight track surfaces along its length that parallel the rotational axis and lie in substantially perpendicular planes which respectively extend to opposite sides of said axis. Each of said tracks is engaged by rollers carried by the outer member at fixed axially spaced locations. Other rollers on the outer member engage the periscope member under radially inward bias to maintain the track surfaces guidingly engaged with the first mentioned rollers.



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SHEET 1 OF 4

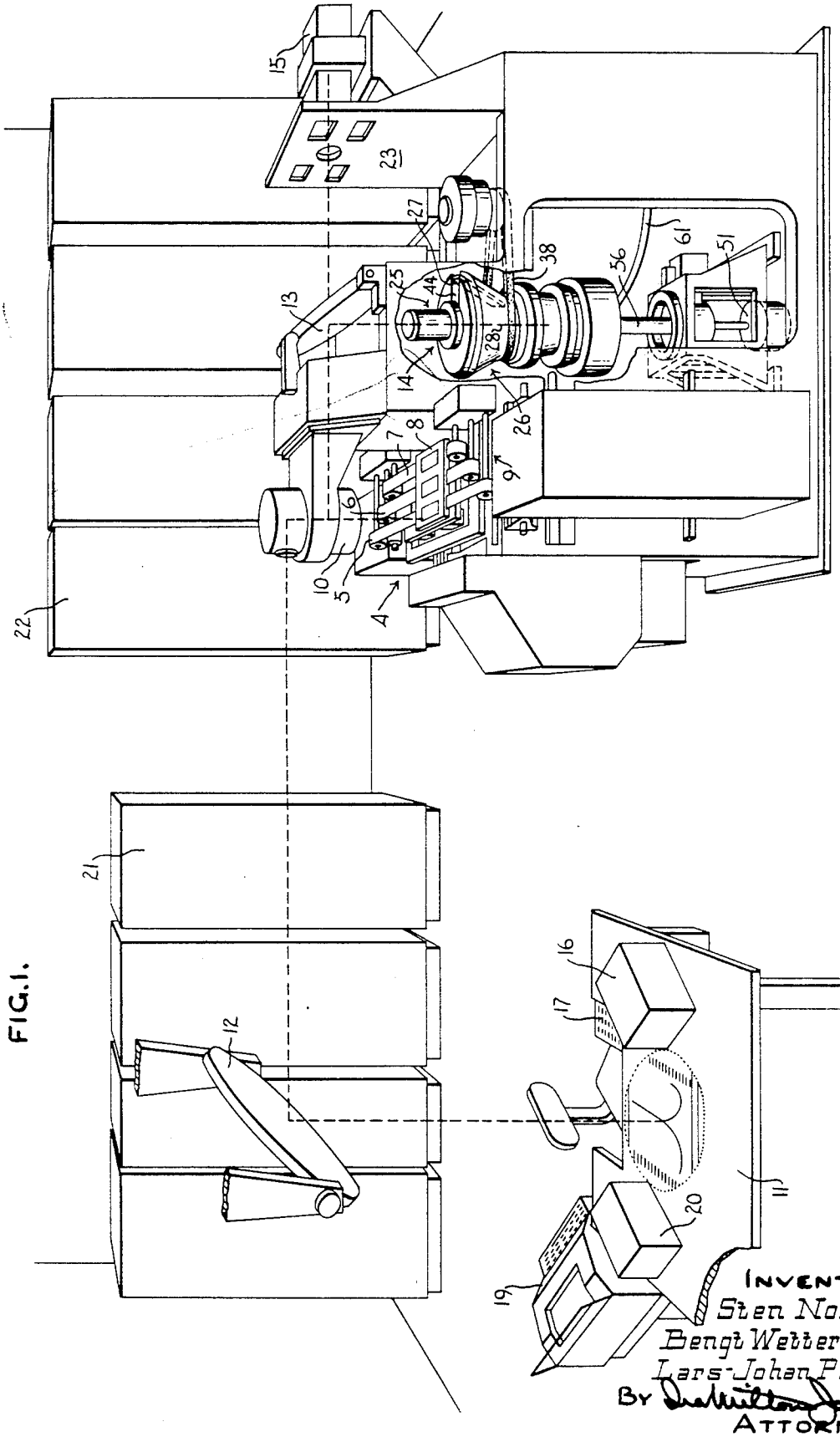
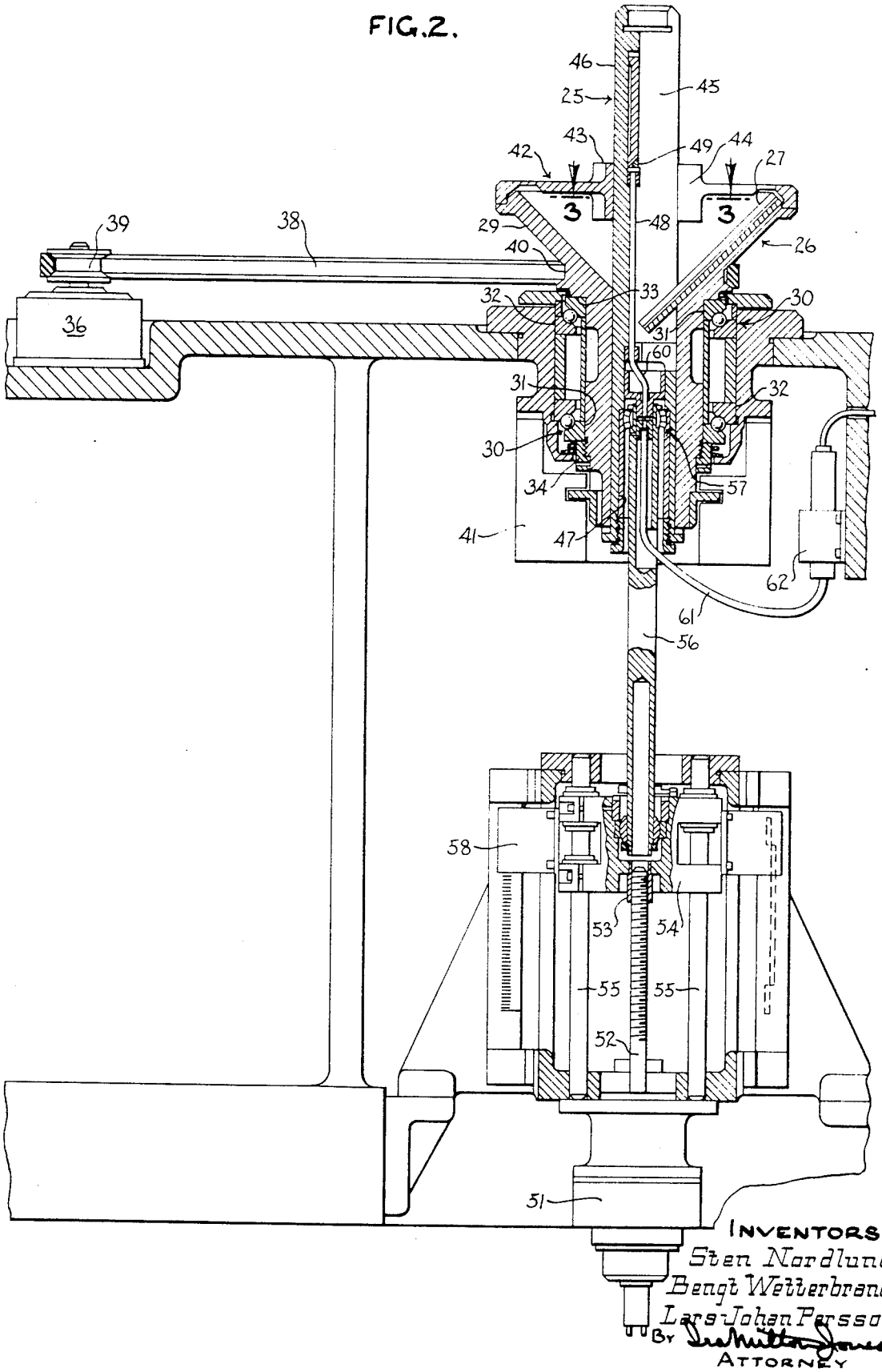


FIG. 1.

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FIG. 2.



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FIG.3.

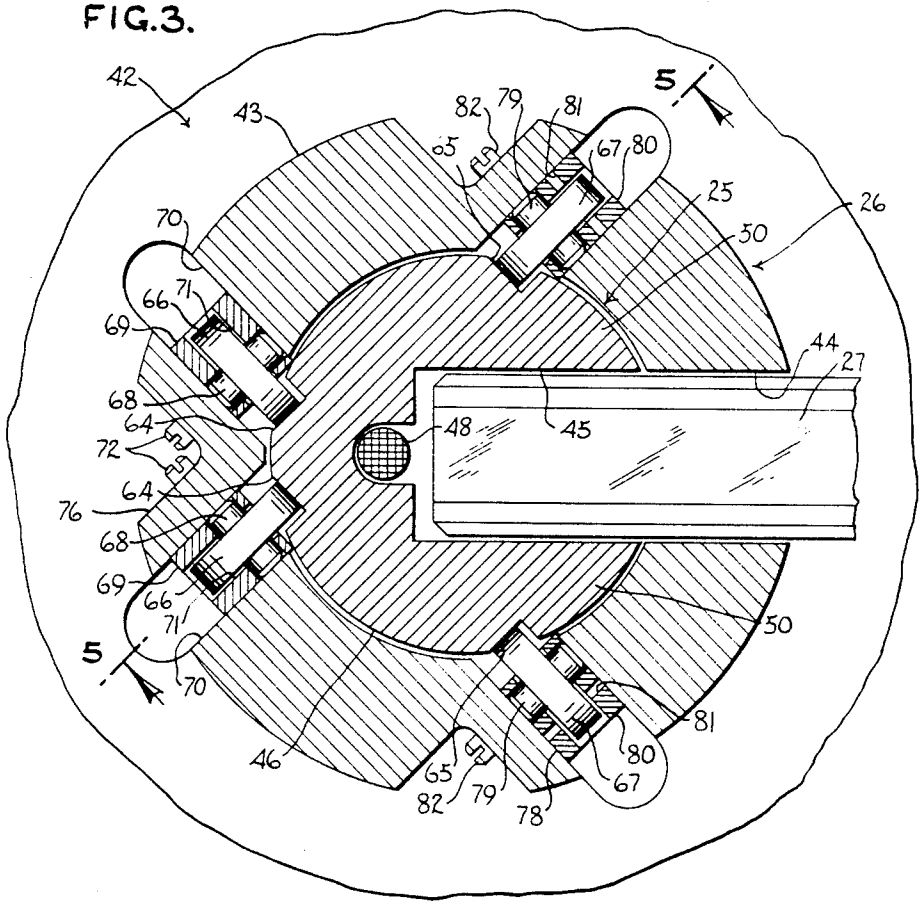
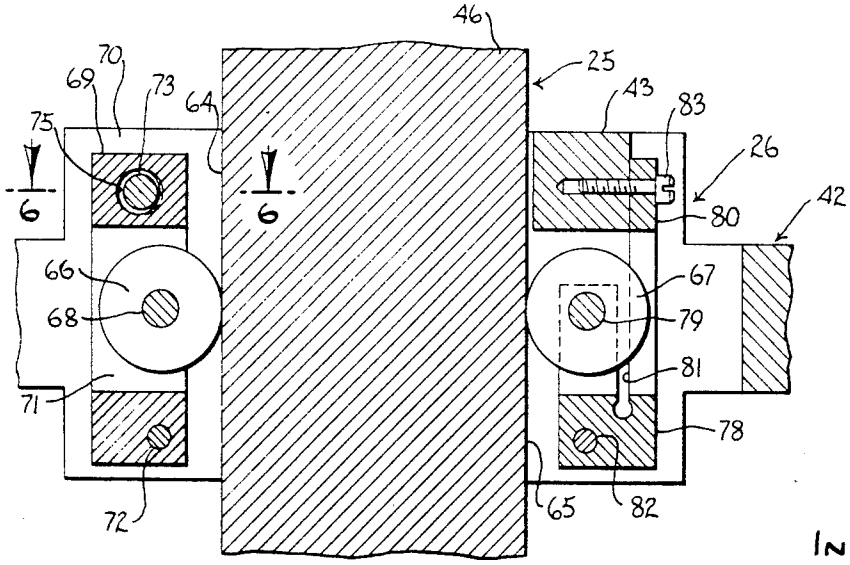


FIG.5.



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FIG. 4.

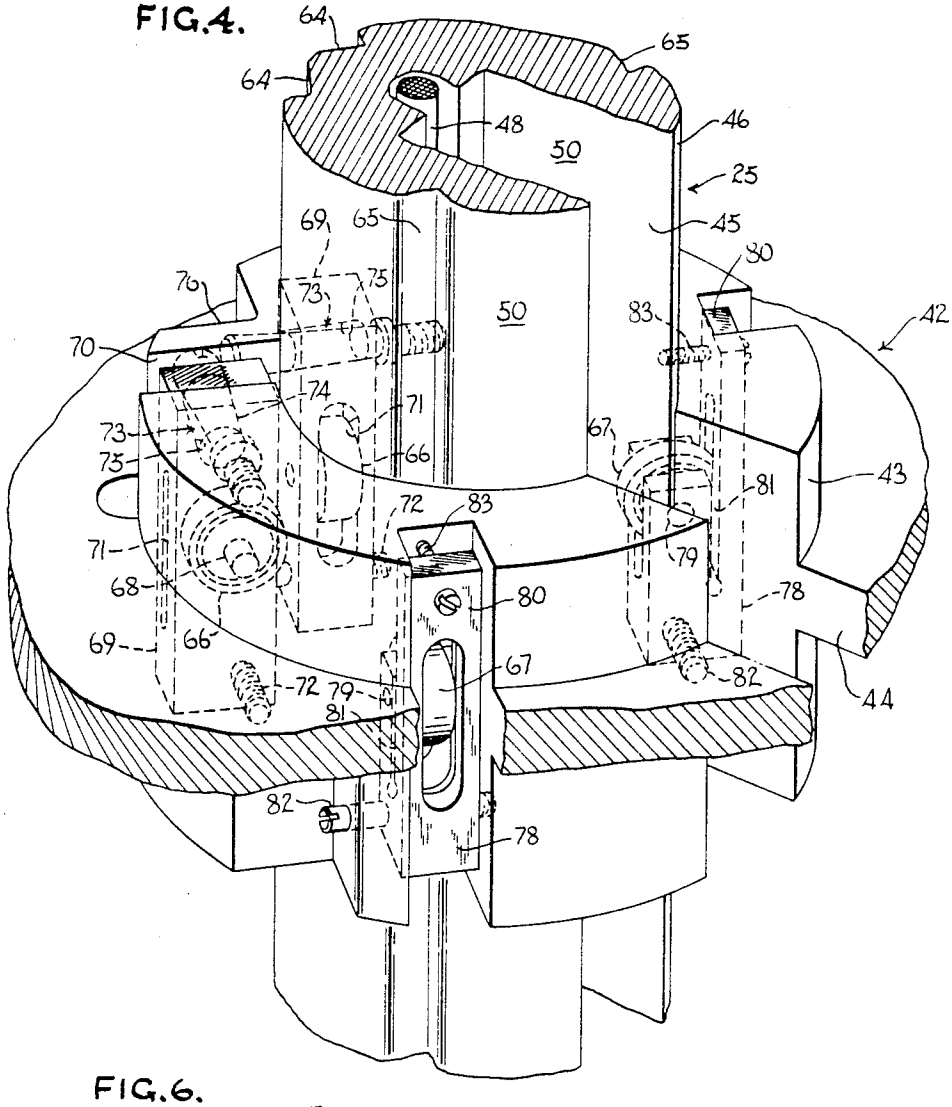
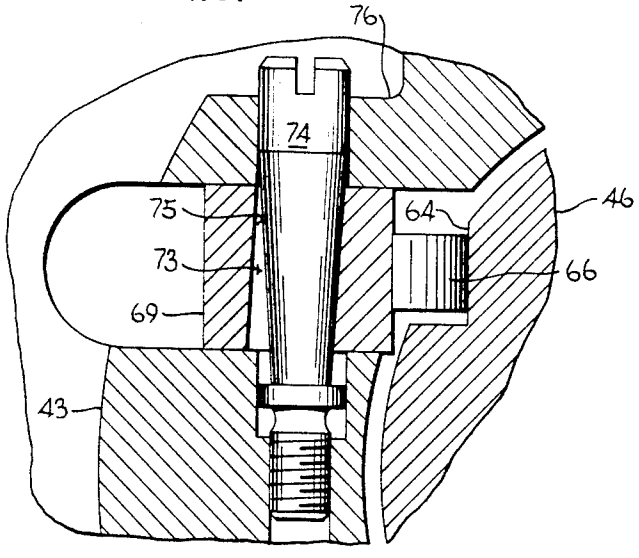


FIG. 6.



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STRUCTURE FOR CONE AND PERISCOPE OF SPIRAL PATH SCANNING MECHANISM

This invention relates generally to apparatus for scanning photographs of the tracks made by charged particles in a bubble chamber or cloud chamber for the purpose of converting the records contained on such photographs to a form that can be used by a computer and ultimately analyzed to provide information about particle interactions and decays in nuclear physics experiments; and the invention relates more particularly to a so-called spiral reader for such photographs, comprising a mirror which moves orbitally about an axis at a substantially high speed, and a periscope which is caused to move parallel to the same axis while rotating with the mirror about that axis. The invention relates, specifically, to structure by which the mirror and periscope are constrained precisely to the motions desired for them.

A bubble or cloud chamber, containing fluid in a condition of equilibrium between the liquid and gaseous states and surrounded by a superconductive electromagnet, is a well-known device used in nuclear physics experiments. When a charged particle is shot into the chamber, it leaves a track of tiny bubbles; and when it encounters another particle (which encounter is called an "event") the particles taking part in the event trace branching tracks which diverge from the point of the encounter. These bubble tracks, although persisting only very briefly (a matter of microseconds) can be photographed stereoscopically to provide a record of the several paths taken by the particles involved in each event. Since the motions of the particles provide a clue to their natures, the study of photographic records of the branching or diverging tracks that denote events is of particular interest.

A reading machine of the type to which this invention relates is used to scan bubble chamber photographs for the purpose of converting the pictorial records of events to a form of data that can be stored in and used by an electronic computer. When a sufficient amount of such data is available, derived from the photographic records of numerous experiments, conclusions can be drawn, on the basis of statistical analysis of the data, about the nature and characteristics of the particles involved in the events being studied.

Inasmuch as valid conclusions can be drawn only on the basis of statistical study of a very large number of experiments, a tremendous amount of film needs to be analyzed—truckloads, in many cases. Automation of the "reading" of the film records is therefore essential to reasonable management and utilization of the data contained in such records.

Each frame of film to be analyzed may contain one or more sets of diverging tracks that signify events, along with numerous other lines that trace the paths of particles that did not take part in events and which are therefore not of interest.

Selection of each part of a frame of film to be scanned is accomplished, at least in part, with the aid of a human operator. As it scans the image on the film, the automatic reader produces signals corresponding to all tracks on the portion of the film being scanned. These signals are fed to a computer which in effect rejects signals corresponding to tracks not of interest and preserves data relating to events selected for analysis.

This invention is based upon the premise that the nature of the tracks to be analyzed is such that the most efficient and useful pattern of scanning is a spiral one in which the origin of the spiral is at the point where several diverging tracks have their junction or vertex that denotes an event.

In a very general way it is an object of the present invention to provide mechanical means for effecting scanning in a spiral scanning path of film records of the character described, which scanning means comprises a mirror that rotates about a fixed axis and is so inclined to said axis as to generate a cone in the course of its rotation, and a periscope having an optical element or eye that faces the mirror and rotates therewith and at the same time moves steadily along the axis about which the mirror rotates.

To be practical for the scientific purpose for which it is intended, a scanning mechanism of the character just described must rotate at a relatively high speed, in order to accomplish its work expeditiously (bearing in mind the tremendous volume of records to be processed); but it must nevertheless embody a very high degree of precision so that the data obtained from each reading will accurately portray the recorded event being read.

It is therefore another object of this invention to provide means for constraining the mirror and periscope in a spiral reader of the character described to exactly the motions prescribed for them so that they remain uninfluenced by centrifugal and other forces which act upon them and which tend to divert them from the desired motions.

With these observations and objects in mind, the manner in which the invention achieves its purpose will be appreciated from the following description and the accompanying drawings. This disclosure is intended merely to exemplify the invention. The invention is not limited to the particular structure disclosed, and changes can be made therein which lie within the scope of the appended claims without departing from the invention.

The drawings illustrate one complete example of a physical embodiment of the invention constructed according to the best mode so far devised for the practical application of the principles thereof, and in which:

FIG. 1 is a general perspective view of reading apparatus embodying the principles of this invention, shown in operative relation to other apparatus with which it cooperates;

FIG. 2 is a vertical sectional view through spiral scanning apparatus embodying this invention;

FIG. 3 is a horizontal sectional view taken on the plane of the line 3–3 in FIG. 2;

FIG. 4 is a fragmentary view, partly in perspective and partly in section, showing the structure by which the periscope member is constrained to rotate with the mirror carrying member and to move up and down relative to the mirror carrying member, exactly parallel to the axis of rotation thereof, the view being taken generally near the top of the mirror carrying member;

FIG. 5 is a fragmentary sectional view taken on the plane of the line 5–5 in FIG. 3; and

FIG. 6 is a fragmentary sectional view taken on the plane of the line 6–6 in FIG. 5.

Referring now more particularly to the accompanying drawings, the numeral 4 designates generally a reading machine in which the present invention is embodied, and FIG. 1 illustrates it in its relationship to apparatus with which it cooperates.

The film to be analyzed or read by means of the reading machine 4 is in the form of long strips, each divided along its length into a number of frames, and each frame usually containing a record of one or more events which are of interest. To facilitate handling, each strip is normally wound onto a reel to form a roll. Inasmuch as each experiment in a bubble chamber is photographed simultaneously by three cameras, focused along coordinate axes, three related rolls of film must be read more or less simultaneously, to coordinate data for each frame in each roll with that for the corresponding frames in the other two rolls. The frames in each roll are successively numbered before the film is presented to the reading machine 4, to facilitate identification of the recorded events.

In FIG. 1, three related strips of film to be scanned by the reading machine are respectively designated 5, 6 and 7. The extend across a horizontal table 8 on the reading machine having three apertures, one for each roll, that are aligned with a suitable light source (not shown) which is located beneath the table. Film transport means, comprising a suitable capstan drive 9, provides for advancing the rolls of film simultaneously across the table 8, to permit successive frames on each roll to be brought into register with the apertures in the table for the purpose of scanning. In addition, the film table is capable of bodily movement in all horizontal directions to permit any

selected portion of a frame of film to be brought into alignement with the axis of an objective head **10** which is fixed above the film table and which comprises reflecting means. A companion application, Ser. No. 854,147, filed Aug. 28, 1969, discloses means for constraining the film take up and supply reels to move horizontally with the table, to avoid twisting distortion of the film.

The image on the film frame that is under the objective head is projected up into the objective head, thence horizontally in one direction, and finally down onto the top surface of an operator's table **11**. An obliquely disposed mirror **12** above the operator's table receives the image from the objective head and reflects it downwardly onto the operator's table.

The image is also projected from the objective head in the opposite horizontal direction, toward a half-silvered mirror **13**, whence it is reflected downwardly into scanning mechanism **14** which is described hereinafter. The image is also projected through the half-silvered mirror into a television camera **15** which receives only a very small portion of the total image on a film frame, corresponding to about a square millimeter of the film around the axis of the objective head. The image of this small area is presented to the operator, in very greatly magnified form, on the screen of a television camera. This highly magnified portion of the total image is used for accurately locating the film table to bring the vertex of the event record to be studied into exact coincidence with the axis of the objective head and hence into coincidence with the scanning axis of the scanning device **14**.

On the operator's table there is a control console **17** for controlling film advance and the horizontal movements of the film table. The operator also has a typewriter **19** for input and output of data and an oscilloscope **20** that gives a graphic representation of light values measured during scanning.

The scanning device **14** is connected with an electronic computer **21** through an adapter **22** which is in itself a form of electronic computer.

Before a set of films is actually scanned or read, it is prescanned to store in the computing apparatus the numbers of those frames that record events of interest and the approximate locations on the frames of the vertices of such events. For the actual scanning operation, the computer so controls the film transport that each in turn of the frames to be studied is brought into register with the apertures in the film table. When a frame has thus been advanced into and locked in the film table, the computer makes a rough adjustment of the table, based on data obtained in the prescanning, and the operator makes the final adjustment by reference to the television receiver **16**. After the first frame is read, the computer automatically shifts the table to properly align the vertices on the corresponding frames of the other two rolls of film.

Because film is dimensionally unstable, each frame of film has spaced apart fiducial marks, corresponding to fixed points in the photographed bubble chamber, and an accurate measurement of the distances between fiducial marks on a frame provides scale data for it from which events recorded thereon can be accurately located in the bubble chamber space. For feeding data into the computer concerning the coordinates of the fiducial marks on each frame, there is a fiducial plate **23** in front of the television camera that has specially shaped slots, and photomultipliers behind the slots register when the images of the fiducial marks align with these slots as the film table moves a frame horizontally. The signals from the photomultipliers are combined with information derived from the table movements to produce information concerning the scale of the frame, which information is stored in the computer and used in conjunction with the signals obtained from the scanning of particle tracks that are recorded on the film.

Scanning can begin as soon as the vertex of an event record to be studied has been brought into coincidence with the optical axis.

The image of an event on a film frame is scanned in a spiral path, and hence the scanning apparatus is known as a spiral reader. The scanning begins at the vertex, progressing outwardly and around, and a signal is produced each time a track on the film record is crossed in the course of such scanning. Since data concerning the radial and angular coordinates of the scan are continuously fed to the computer, the scanning process results in the storing of data which characterizes the event. After the record of a selected event on a frame of film has been scanned, records of the same event on the counterpart frames of the other two rolls of film are similarly scanned, the vertices of the other two records being automatically located by the computer and aligned with the scanning axis. Data from the three scannings of the event are combined by the computer into a form that defines an unambiguous three dimensional curve which characterizes the event, and this is stored in the computer to be available for comparison with similarly obtained data for other events, for the purposes of statistical analysis.

The scanning device **14** by which the photographed image of an event is scanned along the desired spiral path comprises, in general, concentrically arranged inner and outer members **25** and **26**. The outer member **26** carries a plane mirror **27** and is constrained to rotation on a fixed axis. The inner member **25** comprises a periscope and is constrained to both rotation with the outer member and motion relative to it in directions accurately parallel to said fixed axis.

The axis about which the mirror carrying outer member **26** rotates can be considered to coincide with the vertex of an event to be scanned; or, more a accurately, when the film table **8** has been accurately located to dispose a film frame for scanning, the image of the vertex of the event to be scanned is projected exactly along the axis of the outer member, as represented by the broken line **28** in FIG. **1**.

The outer member comprises a generally funnel shaped body **29**, as seen in FIG. **2**, and the mirror **27**, which is elongated and generally rectangular, is secured in a groove in the inner surface of the conical upper portion of that body. The mirror extends lengthwise in the direction radial to the rotational axis (as best seen in FIG. **3**) and it is disposed obliquely to that axis, being inclined, along its length, radially outwardly and upwardly (as shown in FIG. **2**), so that it reflects inwardly toward the axis an image projected down onto it parallel to the axis. Thus as the mirror is carried orbitally in consequence of rotation of the outer member, it defines a reflecting cone and scans a circular area of the film frame that has at its center a vertex denoting an event. At every instant during such scan the mirror reflects toward the axis a striplike radially extending portion of that circular area. Note that the bottom portion of the mirror extends across the rotational axis, so that the strip reflected by the mirror will always include the vertex of the event.

As the inner periscope member **25** rotates with the mirror, its eye always faces the mirror. Hence, as the periscope moves upwardly parallel to the axis of rotation, it scans along the strip being scanned by the mirror. And since that strip is moving angularly around the vertex at a steady rate, and the periscope is scanning at a steady rate along that strip, the net effect of the combined scanning motions is the desired spiral scan. A companion application, Ser. No. 853,830, filed Aug. 28, 1969, discloses means for adjustably masking the periscope eye for varying the area of the mirrored image that the periscope scans.

The embodiment of the mirror and periscope scanning principle into actual apparatus has involved certain complex problems. The changes in light value picked up by the periscope eye in the course of its scan must be converted into electrical signals in order to provide an input that can be utilized by a computer, and the transducer that effects this conversion must of course be operating all during the scanning process in spite of the fact that the periscope has a combined rotational and axial motion. The manner in which this is accomplished is explained hereinafter.

Another and more complex problem is posed by the need for a very high degree of precision in the motions of the scanning apparatus. There can be no play, wobble or eccen-

tricity in the rotation of either the inner or the outer member, even though such rotation is at about 1,000 r.p.m. The mirror must not be distorted or displaced by centrifugal forces as it rotates. The up and down motion of the inner periscope member must be truly parallel to the rotation axis. And finally, the optical elements of the periscope must not whip or bow, even though they are spaced somewhat to one side of the axis about which the periscope revolves and comprise a relatively slender and resilient shaft.

To insure a high degree of rigidity for the mirror carrying outer member **26**, its funnel-shaped body member **29** is preferably formed of one piece of cast iron. The lower tubular or spout portion of that body member is journaled in a pair of axially spaced apart angular contact ball bearings **30**, each comprising a radially inner ring **31** and a radially outer ring **32**. The radially inner ring **31** has a frustoconical radially outwardly facing ball race surface, while the radially outer ring **32** has a complementary radially inwardly facing race surface. The two angular contact ball bearings **30** are arranged with their inner rings **31** remote from one another, and therefore the side thrust reaction moments of the two bearings are centered at points that are spaced substantial distances axially outwardly of them, so that the bearings provide good resistance to tilting of the rotating unit. The inner ring **31** of the upper one of these bearings is engaged against a downwardly facing shoulder **33** on the funnel-shaped member, while the inner ring **31** of the lower bearing is is engaged by a nut **34** that is threaded onto the lower end of the tubular portion of that member and can be tightened to the point where all wobble and vibration is eliminated, thus further assuring that the mirror carrying member has true rotational motion.

The mirror carrying member is driven in rotation by an electric motor **36** which is mounted to one side of it and which is connected with it by means of a belt **38** and a drive pulley **39** on the motor. The best is received in a circumferential belt groove **40** around the conical top portion of the mirror carrying member, spaced a small distance above the upper ball bearing **30**.

An angle transducer **41** is operatively associated with the mirror carrying member to issue signals denoting its position of rotation, which signals are utilized by the computer in its processing of scanning information.

An important feature of the scanning apparatus of this invention is a coverlike member **42** which is secured to the top of the funnel-shaped member and which serves the dual function of providing great rigidity to the mirror carrying outer member so that it resists mirror displacing distortion due to centrifugal force, and of steadying the inner periscope member, as described hereinafter, to prevent it from whipping or wobbling. The coverlike member **42** has a central hublike portion **43** through which the inner periscope member **25** extends and has a radially extending slot **44** which opens from the hub portion and which is located directly above the mirror, through which the projected image passes downwardly to the mirror.

The inner periscope member **25** comprises a rigid, elongated body member **46** which is substantially U-shaped in cross section along most of its length, to define a slotlike shaft **45** down which light can pass to the mirror **27**, but which has a tubular lower portion defining a downwardly opening concentric well **47**. The optical elements of the periscope comprise a fiber optic rod **48** which transmits light along its length and a small prism or reflector **49** on the top of the fiber optic rod which constitutes the eye of the periscope and which receives light from the mirror **27** and reflects it down into the rod **48**.

The leg portions **50** of the U-shaped body member **46** straddle the mirror **27** with a small clearance, as best seen in FIG. **3**. The fiber optic rod **48** is secured in a small recess or groove in the body member **46** that opens to the light shaft **45** between its legs **50** and extends lengthwise along it.

The periscope comprising the body member **46**, the prism or reflector **49** and the fiber optic rod **48** is moved up and down by means of a reversible electric motor **51** which is mounted beneath the rotating members. The shaft **52** of the motor, which projects upwardly substantially concentrically with the inner and outer members **25** and **26**, is threaded along its length to cooperate with a nut **53** on a yoke **54**. Fixed upright guide rods **55**, spaced to opposite sides of the motor, guide the yoke, confining it and the nut to motion up or down, depending upon the direction of motor rotation. Such motion of the yoke is transmitted to the periscope by means of a connecting shaft **56** which is substantially concentric with the rotating members and the motor shaft **52** and which has its lower end nonrotatably secured to the yoke **54**. The upper end portion of the connecting shaft **56** is received in the well **47** in the lower portion of the periscope body and is connected with the periscope body by means of a suitable axial thrust bearing **57** which provides for rotation of the periscope body relative to the connecting shaft but constrains the periscope to axial motion with it. The connections of the connecting shaft **56** with the yoke **54** and with the axial thrust bearing **57** comprise spherical joints that compensate for any misalignment between the axis of the motor **51** and that of the rotating inner and outer members.

A position responsive transducer **58** that is associated with the axial drive mechanism feeds signals to the computer that denote the axial position of the periscope.

The prism or reflector **49** is necessarily eccentric to the axis about which the inner and outer members rotate, inasmuch as the mirror extends across that axis, and the fiber optic rod **48** must likewise be spaced from that axis along most of its length. Near its bottom, however, the fiber optic rod has an offset bend, as at **60**, so that its bottom end is on the axis and is located in or near the bearing connection between the periscope body member **46** and the connecting shaft **56**. Another length of fiber optic, designated **61**, extends through the upper portion of the connecting shaft **56** (which is tubular to accommodate it) with its upper end closely adjacent to the bottom end of the rotating fiber optic rod **48**. The lower nonrotating fiber optic rod extends laterally out of the connecting shaft through a side aperture in the latter, and over to a light responsive transducer or photoelectric cell **62** which is mounted in a fixed position near the scanning mechanism. The flexibility of the fiber optic accommodates the up and down motion of the connecting shaft **56** relative to the transducer **62**. It has been found that light losses across the joint between the two lengths of fiber optic are not significant.

As explained above, it is essential that there be no rotational play between the inner and outer members **25** and **26**, so that the periscope accurately faces the mirror at all times, and that the inner periscope member, while rotating, move exactly parallel to the rotation axis. To this end the periscope body member **46** is formed with certain guide surfaces or ways that extend along its length, and these cooperate with pairs of surface engaging elements that are carried by the outer member **26**, one surface engaging element of each pair being on the hub portion **43** of the coverlike member **42** and the other being on the lower end of the tubular portion of the outer member **26**, beneath the lower bearing **30**.

Specifically, the periscope body member **46** has two track surfaces **64** that extend lengthwise of it along its bright portion, at the side of the periscope body remote from the mirror, and which lie in substantially perpendicular planes that are parallel to the axis of rotation but seen in a cross section, respectively extend to opposite sides of that axis and of a symmetrical plane through that axis. Hence the track surfaces **64** face obliquely radially outwardly and in opposite circumferential directions. Special pains are taken with the formation of the track surfaces **64** to insure their accuracy in flatness, straightness and parallelism with the axis of rotation. Hence when these track surfaces are maintained in running engagement with surface engaging elements at fixed axially spaced locations on the outer mirror carrying member **26**, the track surfaces and surface engaging elements cooperate to confine the periscope body **46** to motion exactly parallel to the axis of rotation. Furthermore, since the track surfaces face obliquely,

one in the direction of rotation and one in the opposite direction, such cooperation constrains the periscope body member to rotate with the mirror carrying outer member **26**.

The cooperation just described is assured by means of yieldingly biased surface engaging elements (described hereinafter) on the mirror carrying member which engage two other lengthwise extending steadying surfaces **65** on the periscope body member, on the leg portions **50** thereof. The steadying surfaces **65** are spaced substantial distances circumferentially from the tracks **64**, and each preferably faces in a direction substantially opposite to one of the tracks **64**. While the steadying surfaces **65** should be generally straight, flat and parallel to the axis of rotation and hence parallel to the track surfaces **64**, it will appear as the description proceeds that the steadying surfaces need not be formed with the same high degree of accuracy as the track surfaces **64**.

The several surface engaging elements preferably comprise rollers **66** and **67** that are carried by the outer mirror carrying member **26** at the locations described above. The rollers that cooperate with the track surfaces **64** are designated **66**, those that engage the steadying surfaces **65** are designated **67**.

Each of the rollers **66** is journaled on a shaft **68** that is carried by a blocklike holder **69** which is rigidly but adjustably secured to the mirror carrying member **26**. These holders are received in rather closely fitting slots **70** that extend through the wall of the mirror carrying member, and each holder, in turn, has a slot **71** through it in which the roller rides.

Each holder is secured to the mirror carrying member by means of a pair of bolts **72** and **73** (see FIG. **5**) that are respectively spaced above and below the roller and extend parallel to its axis. One of these bolts, designated **72**, fits closely in a hole through the holder and serves as a pivot about which the holder can swing for adjusting motion to carry the roller radially inwardly and outwardly. The other bolt **73**, as best seen in FIG. **6**, has a conically tapered portion and a cylindric head **74**, and the hole **75** in the holder **69** in which it is engaged is inclined relative to the axis of roller **66** to extend parallel to the generatrix of the tapered portion at the inner side of the latter, so that the tapered portion is engaging the hole **75** by a line along the hole. The bolt is guided in its inner as well as its outer end by a shoulder and the cylindric head **74** respectively, so that as the bolt **73** is screwed into its threaded hole in the mirror carrying member, its tapered portion effects radially inward adjustment of the roller **66**. Since each of the track surfaces **64** is engaged by a pair of rollers **66**, at locations spaced apart lengthwise of the track surface, it will be evident that the adjusting bolts **73** can be employed for aligning the direction of up and down motion of the periscope to be exactly parallel with the rotational axis. A suitably formed bay or cutout **76** in the outer surface of the member **26** provides for adjusting access to the heads of the bolts **73**.

The rollers **67** that comprise the surface engaging elements which cooperate with the steadying surfaces **65** engage those surfaces under yielding bias to thus urge the periscope body member **46** bodily in the direction to maintain the track surfaces **64** engaged with the rollers **66**. Furthermore, because the rollers **67** engage the steadying surfaces **65** under yielding bias, small departures from true flatness and straightness in the steadying surfaces are accommodated by bodily yielding motion of the rollers **67**.

The supporting means for each roller **67** comprises a generally U-shaped holder **78** that has its legs straddling the roller and bridged by the shaft **79** of the roller, and a resilient tongue **80**, preferably integral with the U-shaped holder and defined therefrom by a slot **81**. The tongue **80** projects a substantial distance above the holder proper. A single bolt **82** extends through the bight portion of the holder and is threaded into the outer member **26**, to provide a pivot about which the holder can swing to carry the roller **67** toward and from the periscope body. An adjusting screw **83** extends through the upper end portion of the tongue **80** and is threaded into the outer member to maintain the upper end portion of the tongue flexed radially inwardly. The adjusting screw **83** can be tightened to increase the force by which the roller **67** is urged against the periscope body, or it can be loosened to decrease the biasing force.

From the foregoing description taken with the accompanying drawings it will be apparent that this invention provides a spiral reader having a mirror which is accurately constrained to rotation in a cone-defining orbit and a periscope which is constrained to rotate with the mirror, so as to face the mirror at all times, and which is also compelled, while so rotating, to move in directions accurately parallel to the axis about which it and the mirror rotate.

We claim:

1. In a spiral scanner comprising concentrically arranged inner and outer members, the outer member being confined to rotation on an axis and carrying a mirror which extends obliquely to said axis and across the same so as to move in a cone-defining orbit in consequence of rotation of the outer member, and the inner member comprising a periscope which extends lengthwise parallel to said axis at one side thereof and which is moved in opposite directions parallel to said axis for scanning the mirror, means constraining the inner member to rotate with the outer member, so that light receiving means of the periscope always faces the mirror, and to move accurately parallel to said axis, said last named means comprising:

A. means on one of said members defining a pair of elongated track surfaces that extend accurately straight and parallel to said axis, said track surfaces being located eccentrically to said axis and lying in substantially transverse planes which respectively extend to opposite sides of said axis so that one of said track surfaces faces obliquely in one rotational direction and the other faces obliquely in the opposite rotational direction;

B. two pairs of surface engaging elements carried by the other member, one pair for each of said track surfaces, the surface engaging elements of each pair being at locations fixed on said other member that are spaced apart a substantial distance in the direction of said axis and the several surface engaging elements being engageable with their respective track surfaces to constrain the inner member to rotation with the outer member and to motion relative to the outer member in directions accurately parallel to said axis; and

C. cooperating means on said members for maintaining a biasing force on the inner member in a direction transverse to the axis and generally transverse to said track surfaces to maintain said track engaging elements engaged with said track surfaces, the last mentioned means comprising other surface engaging elements carried by one of said members and engaging surface portions of the other member that are circumferentially spaced from said track surfaces, said other surface engaging elements being yieldingly biased to react between the member by which they are carried and said surface portions of the other member.

2. The spiral scanner of claim **1**, further characterized by each of the surface engaging elements of said two pairs thereof comprising:

A. a roller; and

B. means journaling the roller on said other member with the axis of the roller transverse to the first named axis and parallel to the track surface engaged by the roller.

3. The spiral scanner of claim **2**, further characterized by said journaling means being adjustable in directions generally toward and from the first mentioned axis.

4. The spiral scanner of claim **1**, further characterized by said surface portions circumferentially spaced from the track surfaces being on the same member with the track surfaces and comprising a pair or elongated steadying surfaces, one for each track surface, each of said steadying surfaces being spaced a substantial distance circumferentially from its track surface and lying in a plane substantially parallel to that of its track surface but facing in a direction generally opposite to that in which its track surface faces.

5. The spiral scanner of claim 4, wherein said steadying surfaces are on the inner member, further characterized by said other surface engaging elements comprising:

A. a pair of steadying rollers for each of said steadying surfaces;

B. a holder for each steadying roller upon which the steadying roller is journaled for rotation;

C. means securing each holder to the outer member for swinging motion of the holder about a pivotal axis which is substantially parallel to the steadying roller axis and to its steadying surface, transverse to the first named axis, and spaced from the steadying roller axis in one direction lengthwise of the first named axis, so that the steadying roller is carried bodily in directions generally transverse to the first mentioned axis in consequence of swinging motion of the holder;

D. a resilient tongue for each holder having one end anchored to the holder and having its other end spaced a substantial distance from said pivotal axis; and

E. cooperating means on the outer member and on said other end portion of each tongue for adjustably maintaining said other end portion of the tongue in a position such that the tongue is flexed to apply a desired biasing force to the holder by which the holder is urged to swing about the pivot axis in the direction generally toward the first mentioned axis.

6. Means for scanning a projected image in a spiral path, comprising:

A. a substantially funnel-shaped mirror-carrying member having;

1. a conical upper portion, and

2. a tubular lower portion;

B. means mounting the mirror-carrying member for rotation about its axis;

C. an elongated plane mirror secured to the inner surface of the conical upper portion of the mirror-carrying member and extending lengthwise therealong at an upward inclination to the axis but with its lower portion extending across the axis, said mirror being thus arranged to move in a cone-defining orbit in consequence or rotation of the mirror-carrying member;

D. an elongated periscope body member received in the mirror-carrying member for rotation therewith and for lengthwise motion in opposite axial directions relative thereto, said periscope body member having a substantially U-shaped cross section with its legs straddling the mirror and defining between them a slotlike light shaft that extends downwardly to the mirror;

E. means fixed to the periscope body member for transmitting light lengthwise therealong, said means providing a light receiving surface optically aligned with the mirror;

F. a rigid coverlike member secured to the top of the conical upper portion of the mirror-carrying member to prevent distortion of the mirror under the effects of centrifugal force, said coverlike member having;

1. a central hublike portion through which the periscope body member projects upwardly, and

2. a slot opening radially from said hublike portion and registering with the light shaft in the periscope body member.

G. means on the periscope body member defining circumferentially spaced apart guide surfaces which extend axially therealong and which face obliquely to planes lying on the axis of rotation;

H. surfaces engaging elements on said hublike portion engaging said guide surfaces; and

I. other surface engaging elements on the lower end of the tubular portion of the mirror-carrying member, also engaging said guide surfaces and cooperating with the first mentioned surface engaging elements to constrain the periscope member to rotate with the mirror-carrying member and to move lengthwise relative thereto in directions parallel to the axis of rotation.

7. The scanning means of claim 6, further characterized by:

A. two of said guide surfaces being master surfaces on the bight portion of the periscope body member, at the side thereof remote from the light shaft, which face in opposite obliquely circumferential directions and are accurately straight and parallel to the axis of rotation;

B. there being a guide surface also on the outer surface of each of the leg portions of the periscope body member, one for each master surface but facing in substantially the opposite direction;

C. the first mentioned surface engaging elements comprising:

1. four rollers, one for each of said guide surfaces,

2. means mounting the two of said rollers that engage the master guide surfaces on said hub like portion, for rotation on axes that are fixable at different positions of adjustment generally toward and from the axis of rotation,

3. means rotatably mounting the other two of said rollers on said hublike portion for bodily motion generally toward and from the master surfaces, and

4. means reacting between said hublike portion and said other two rollers to bias the latter in the direction toward the periscope body member to thereby maintain the master surfaces engaged with their respective rollers; and

D. said other surface engaging elements comprising;

1. four rollers, one for each of said guide surfaces,

2. means mounting the two of said last mentioned four rollers that engage the master guide surfaces on the mirror-carrying member for rotation on axes that are fixable at different positions of adjustment generally toward and from the axis of rotation,

3. means rotatably mounting the other two of the last mentioned four rollers on the mirror-carrying member for bodily motion generally toward and from the master surfaces, and

4. means reacting between the mirror-carrying member and the last mentioned other two rollers to bias the latter in the direction toward the periscope body member, to thereby maintain the master surfaces engaged with their respective rollers.

8. In a spiral scanner comprising concentrically arranged inner and outer members, the outer member being confined to rotation on an axis and carrying an elongated mirror which extends obliquely to said axis and across the same and faces obliquely toward and along said axis so as to define a reflective cone in consequence of rotation of the outer member, and the inner member comprising a periscope which extends lengthwise parallel to said axis at one side thereof, means constraining the inner member to rotate with the outer member, so that the light-receiving means of the periscope always faces the mirror, and constraining the inner member to move lengthwise accurately parallel to said axis for scanning of the mirror by the periscope, the last mentioned means comprising:

A. means on the inner member defining a pair of elongated track surfaces that extend accurately straight and parallel to said axis, said track surfaces being located eccentrically to said axis and lying in substantially transverse planes which respectively extend to opposite sides of said axis so that one of said track surfaces faces obliquely in the direction of rotation and the other faces obliquely in the opposite direction;

B. means on the inner member defining a pair of elongated steadying surfaces, one for each track surface, each of said steadying surfaces being spaced a substantial distance circumferentially from its track surface and being substantially parallel to its track surface but facing in a direction generally opposite to that in which its track surface faces;

C. a first two pairs of rollers on the outer member, one pair for each of said track surfaces, the rollers of each pair having journals fixed on the outer member at locations that are spaced apart a substantial distance in the direction of said axis, said rollers being rollingly engagea-

ble with their track surfaces to constrain the inner member to rotation with the outer member and to motion relative to the outer member in directions accurately parallel to said axis;

D. a second two pairs of rollers, a pair for each of said steadying surfaces; and

E. means freely rotatably mounting each of said second two pairs of rollers on the outer member with the rollers of each pair spaced apart in the direction of said axis, said last named means comprising biasing means by which the rollers of said second two pairs are maintained engaged with their respective steadying surfaces under yielding bias by which the rollers of the first two pairs are maintained in firm rolling engagement with their respective track surfaces.

9. The spiral scanner of claim 8 wherein the outer member comprises a substantially funnel-shaped body with a conical upper portion and a tubular lower portion, and wherein the inner member comprises a periscope body member having a U-shaped cross section, the legs of which straddle the mirror and define a slotlike light shaft that extends downwardly to the mirror, further characterized by a cover like member on the top of said funnel-shaped body to reinforce the same and prevent distortion of the mirror, said coverlike member having

1. a hublike portion through which the periscope body member projects and upon which are mounted one of each of said two pairs of roller; and
2. a slot opening radially from said hublike portion and registering with the light shaft to admit light thereto.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,572,883 Dated March 30, 1971

Inventor(s) Sten Nordlund

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2 line 66: "the" should be --They--

Column 3 line 23: After "television" insert --receiver 16 that is connected with the television--

Column 3 line 1&2: "aligne-ment" should read --align-ment"

Column 4 line 27: delete "a" after --more--

Column 5 line 35 change "best" to --belt--

Column 8 line 70 "or" should be --of--

Column 9 line 41 change "or" to --of--

Column 9 line 61 change the "period" to a --comma

Column 9 line 66 change "surfaces" to --surface--

Column 12 line 12 "roller" should be --rollers--

Signed and sealed this 31st day of August 1971.

(SEAL)

Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of P