Nov. 20, 1951

J. D. STRONG

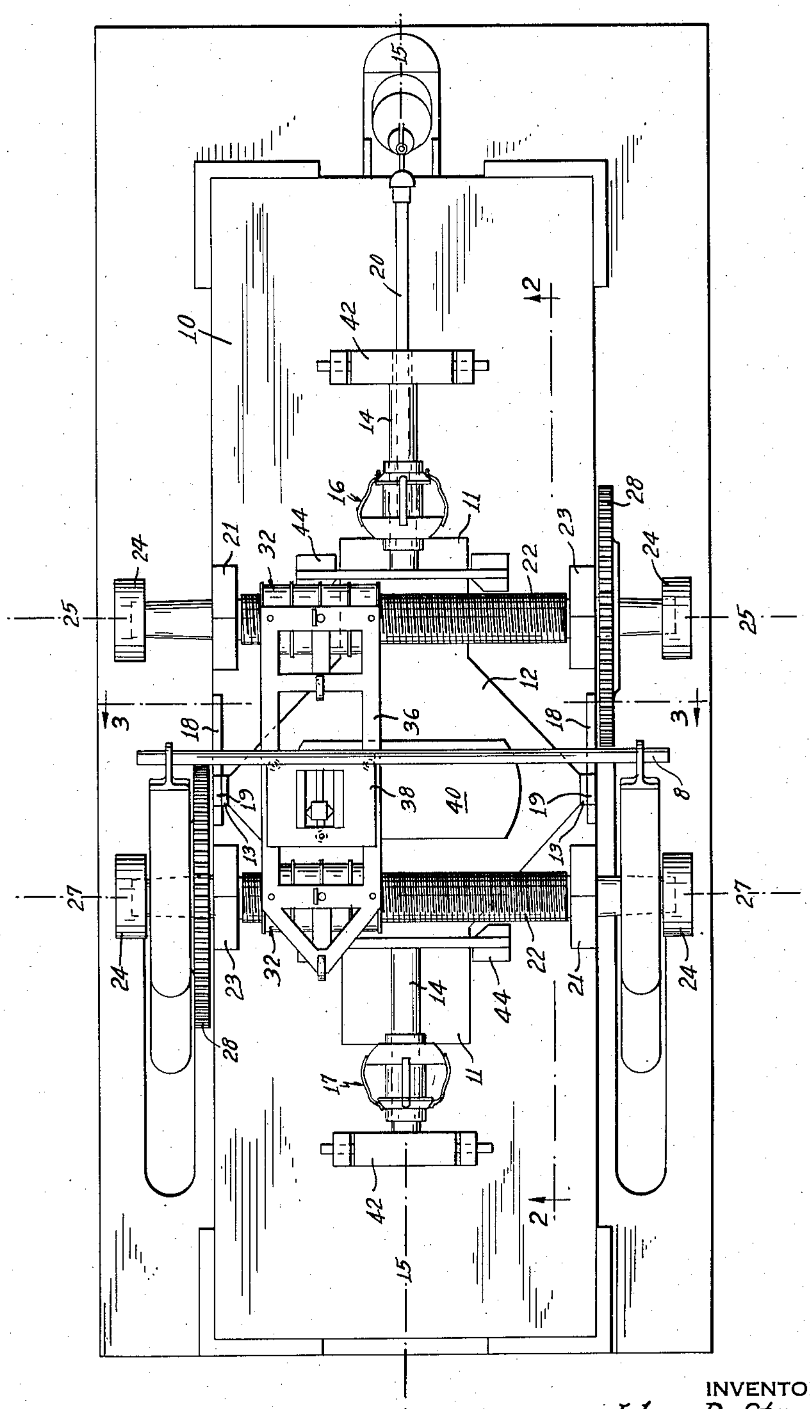
2,575,367

RULING ENGINE

Filed May 31, 1950

3 Sheets-Sheet 1

FIG. 1



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Nov. 20, 1951 J. D. STRONG 2,575,367

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Filed May 31, 1950 3 Sheets-Sheet 2

FIG. 2

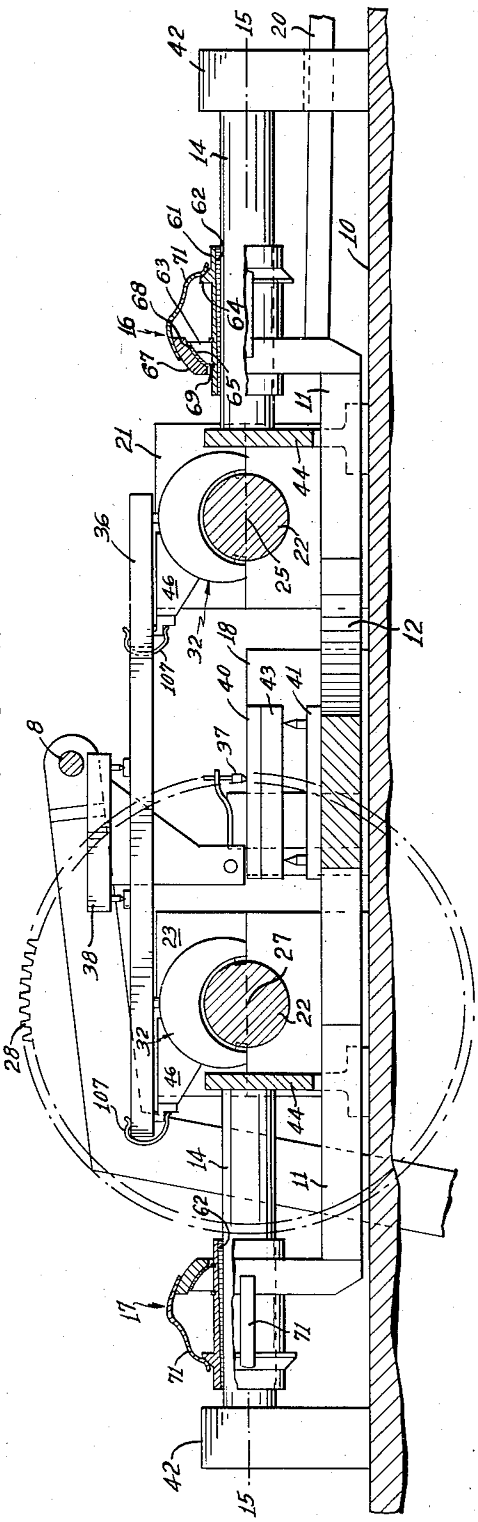
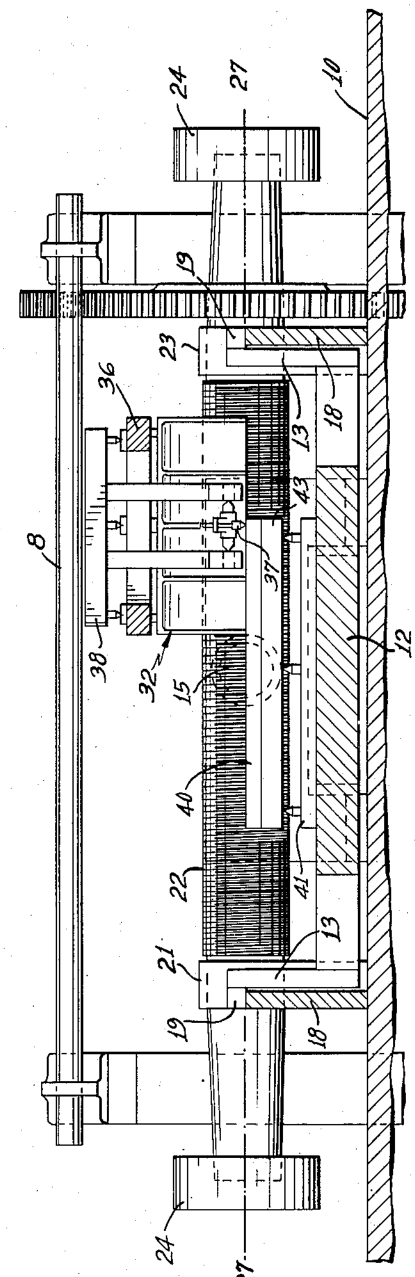


FIG. 3



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Filed May 31, 1950 3 Sheets-Sheet 3

FIG. 4

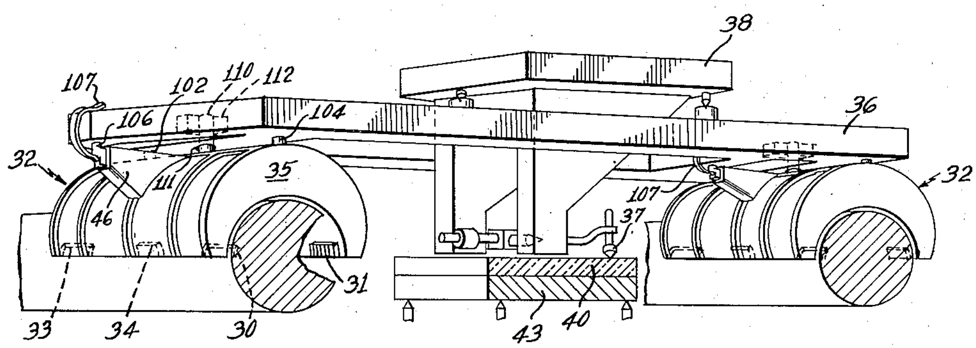
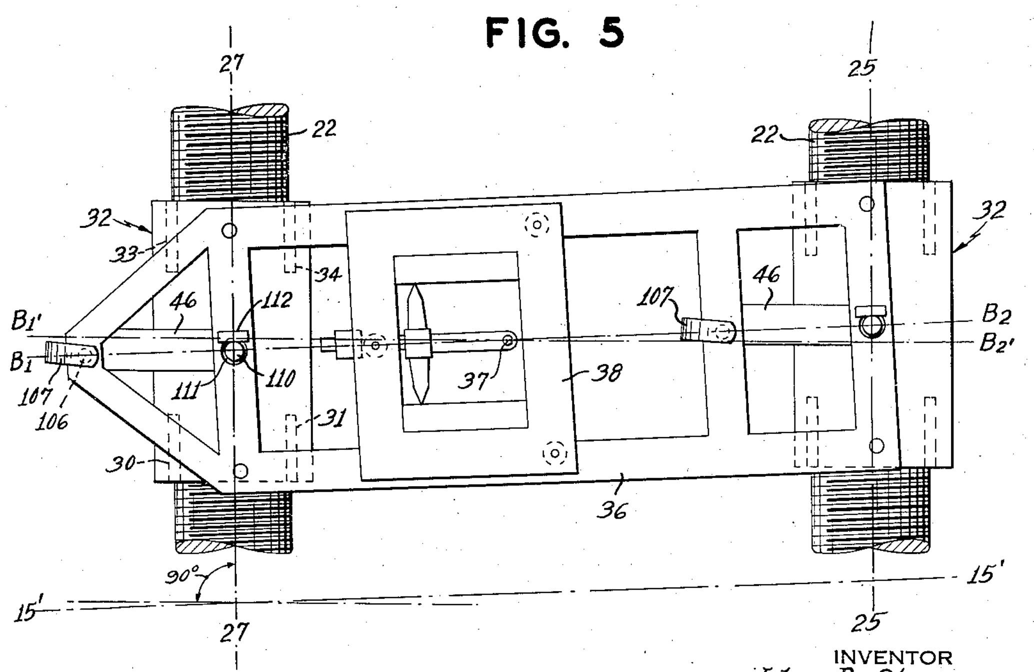


FIG. 5



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Patented Nov. 20, 1951 **2,575,367**

UNITED STATES PATENT OFFICE

2,575,367

RULING ENGINE

John D. Strong, Baltimore, Md.

Application May 31, 1950, Serial No. 165,237

18 Claims. (Cl. 33—32)

1

This invention relates to ruling engines for the manufacture of diffraction gratings. To produce gratings adequate to meet the needs of modern spectrometric research, engines are required capable of ruling up to 15,000 or more lines per inch on a blank, over an area several inches wide. The blank is typically of glass covered with an evaporated metal coating. The lines must be equally spaced and parallel to an extremely high degree of accuracy if the spectra produced thereby are not to contain false lines or be otherwise imperfect. According to the present invention a ruling engine is provided in which the blank to be ruled is reciprocated in a fixed path while the ruling tool is progressively moved with respect to this path. Rotation of the blank and the ruling of fanned lines is thus prevented. A carriage moving on fixed ways serves to reciprocate the blank while two lead screws journaled above and with their axes parallel and transverse to the path of the carriage are engaged by nuts. A connector bar resting on the nuts supports the ruling tool between the lead screws.

In a preferred embodiment of the invention the nuts engage the lead screws only in the vicinity of the horizontal median plane of the latter. This gives to the motion of the ruling tool a high degree of immunity from the sag of the lead screws between their bearings.

According to another feature of the invention the nuts, which engage the screws over two arcs adjacent opposite ends of a diameter of the screw cross section, grip the screws tightly when they are at rest but release them during pawling of the screws by virtue of a wing on each nut which extends transversely of the nut axis for a tractile connection with the connector bar on the side of the nut from which the surface of the screw recedes during rotation. Relative rotation of the screws and nuts therefore acts to disengage the two.

According to another feature of the invention the driving connection between the nuts and the connector bar is provided by a stud or pivot protruding above each nut into the connector bar for engagement therewith. The pivot or stud is at the mid-point of the axial length of the nut so that the position of the connector bar and hence of the ruling tool is immune to rotations of the nuts about a vertical axis such as would be caused by drunkenness of the screw thread or by lifting of the nuts as a whole due to thickened oil films on the screws.

In a preferred construction according to the

2

invention the screws, having threads of the same sense of rotation, are mounted with their axes parallel but not quite perpendicular to the line of motion of the carriage. Instead the screw axes depart from such perpendicularity by the helix angle of the path described by the pivots above referred to, the nuts being considered as rotating about the screws. At the same time one nut is advanced with respect to the other to the extent required to bring the line joining the two driving connections between the connector bar and the nuts into parallelism with the line of motion of the carriage and hence with the helical path of the pivots. The position of the ruling tool crosswise of the grating blank is thereby made substantially independent of small rotations executed by the nuts under the influence of their friction with the screws. The ruling tool is preferably supported in the vertical plane passing through the two driving connections and substantially in the plane defined by the two screw axes. Its position is therefore substantially immune from rotation of the nuts about either horizontal or vertical axes transverse to the screw axis due to errors in the screw thread.

According to another feature of the invention the carriage on which rests the blank to be ruled is supported for reciprocation on a pair of flat ways, and is guided in its motion by a pair of cylindrical ways which are engaged by sleeve bearings connected to the carriage. This construction gives the carriage motion a high degree of immunity from variations in the thickness of oil films, from thermal effects and from friction and wear. Preferably moreover the cylindrical ways have their axes collinear and in or substantially in the plane of the screw axes, and the flat ways by which the weight of the carriage is supported lie also in or near this plane. Support and guidance of the carriage by ways so disposed makes the position of the ruling tool substantially immune to such rotations of the carriage about the axis of the cylindrical ways as may unavoidably occur.

These and other features of construction hereinafter described combine to mitigate the inevitable imperfections of material and workmanship which are encountered, and contribute to make possible a simpler and more standardized ruling procedure than is possible with the engines of the prior art.

In the accompanying drawings

Fig. 1 is a plan view of a ruling engine according to the present invention;

Fig. 2 is a sectional elevation of the engine of

Fig. 1 taken along the line 2—2 of Fig. 1, certain parts being broken away for clarity;

Fig. 3 is a sectional elevation taken along the line 3—3 of Fig. 1;

Fig. 4 is a perspective view of the nuts and connector bar of the engine of Fig. 1, and

Fig. 5 is a plan view of the lead screws, nuts and connector bar of the engine of Fig. 1.

In the ruling engines of the prior art the ruling tool is reciprocated on crossways once for each line to be ruled, and the grating blank is advanced between working strokes on ways transverse to the crossways by means of a precision lead screw. Thus these engines of the prior art resemble a tool room shaper in which the tool is moved relative to the work, the work being shifted at each working stroke. Minute progressive rotation of the blank as it is advanced over the ways of such prior art engines results in lack of parallelism in the ruled lines, and this constitutes a serious defect in the resulting gratings, regardless how perfect the screw and how uniform its rotation may be. According to the present invention instead the blank is reciprocated always over the same path by means of a carriage mounted on ways, and the ruling tool is moved transverse to the path of the blank by means of a supporting structure carried by two nuts each of which rides on a precision lead screw. The engine of the present invention therefore resembles a tool room planer in which the work is moved relative to the tool, the position of the tool being advanced by a small amount at each working stroke.

This form of construction is illustrated in Fig. 1, showing in plan an engine according to the present invention. A bed plate 10 supports the various elements of the engine except for the driving mechanism and certain auxiliary apparatus. A carriage 12, with the blank 40 thereon to be ruled, is supported from flat ways 18 on either side of the bed plate by means of shoes 19 (best seen in Fig. 3) which are attached to the carriage via side wings 13.

The carriage is guided in its reciprocating motion by cylindrical guide ways 14, supported above the bed plate as shown in Fig. 2. The guide ways are engaged by sleeve bearings generally indicated at 16 and 17 which connect with the carriage. The ways 14 are mounted accurately parallel to each other and with their axes 15—15 collinear so that the carriage executes strictly rectilinear motion parallel to the axis 15—15 when pushed and pulled by a link 20 connecting through a bell crank or similar device with a suitable source of power below the bed plate.

Two lead screws 22 are mounted each in bearings 21 and 23 for rotation about parallel axes 25—25 and 27—27 which are parallel to the surface of the bed plate and carriage and approximately perpendicular to the direction of motion of the carriage 12. The screws have affixed thereto dividing heads 28, advanced at each cycle in the motion of the carriage through a fixed increment of angle by pawling mechanism (not shown) which is suitably phased and synchronized with the carriage drive.

Each of the screws includes a central portion having a highly accurate helical thread, preferably of symmetrical V shape. The thread is cut and lapped until the deviations thereof from a nominal diameter along the length of the screw do not exceed a fraction of a fringe when inspected with an interferometer. Of the two bearings for each screw one, as the bearing 21, is a plain bearing and the other, as 23, is a thrust bearing employing a number of zero lead threads to transmit to the bed plate the thrust caused by translation of the ruling tool.

The zero lead thread form of thrust bearing permits the shaft of the screws to protrude beyond the bearings so that counterweights 24 may be provided to minimize the sag of the screws between their bearings. By the use of such counterweights the sag of the screws may be reduced by a factor of 50.

Two nuts, generally indicated at 32, engage the screws. A connector bar 36 rests upon and is supported by the nuts and in turn supports a diamond box 38. The ruling tool or diamond 37 (Fig. 2) depends from the diamond box in position to score a ruling in the grating blank 40 each time the carriage moves in one of its two directions of travel. In the engine shown in Fig. 1 the working stroke of the carriage is from left to right, as the carriage is pulled by the link 20. Suitable mechanism indicated generally at 8 in Fig. 1 lifts the ruling tool from the blank during the return stroke of the carriage.

As indicated in Fig. 2 each of the ways 14 is supported above the bed plate on blocks 42 and 44. The blocks 44 are of bridge form and do not interfere with the motion of the carriage, which has longitudinal extensions 11 passing under the blocks 44 for connection with the sleeve bearings 16 and 17. The block 42 for the right-hand one of the ways in Fig. 1 is suitably apertured to accommodate the link 20.

The bearings 16 and 17 and the carriage are so proportioned that the surface of a blank 40 of standard thickness may be conveniently supported as on a tripod 41 and steel plate 43 to lie in or near the plane of the axes 25—25 and 27—27 of the screws. The blocks 42 and 44 and the screw bearings 21 and 23 are further so proportioned that the axis 15—15 of the cylindrical ways lies approximately in the same plane, as shown in Fig. 2. The carriage is dimensioned so that it may execute the stroke necessary to rule lines of a desired length without bringing the blank into interference with the screws.

The relation of the carriage, of its supporting and guiding ways, of the blank and of the lead screws to each other is further illustrated in Fig. 3. The surface of the blank being ruled, the axis of the guiding ways and the bearing surfaces between the supporting ways 18 and shoes 19 are seen to lie substantially in the plane of the lead screw axes. The blank may of course have a concave, spherical or other curved surface instead of a plane surface. If its surface is curved however, the radii of curvature are large compared to the dimensions of the blank so that the surface to be ruled departs from plane by a quantity which is small compared to the diameter of the screws. It is substantially correct in either case therefore to say that the surface to be ruled and the screw axes are in one plane.

By supporting the carriage from shoes 19 which ride on the flat ways 18 in the plane of the screw axes in which the ruling tool is located, the spacing of the rulings is rendered insensitive to imperfections in the ways 18 and to variations in the thickness of the oil films thereon. Thus a rotation of the blank 40 about the guide axis 15—15 through an angle θ produces a grating groove shift of θ^2 inches at a position two inches laterally removed from the axis 15—15. If a shift of $\theta^2=10^{-6}$ inches is tolerable, a rotation through an angle $\theta=10^{-3}$ inches would be tolerable. This would signify a variation in the straightness of the ways 18 or in the thickness of the oil films thereon of .006 inch, assuming the ways 18 to be

6 inches from the axis 15—15. Variations of this magnitude can be avoided in the construction of the ways 18.

The construction of the ways 14 and of the bearings 16 and 17 which together guide the carriage is also shown in Fig. 2. Each of the ways 14 takes the form of a cylinder, preferably of mild steel, machined and lapped to a highly accurate figure. To limit errors in the resulting grating to a desired value, it is essential that the motion of the carriage be true and constant within limits of the order of a few millionths of an inch. Accuracies of this order are not readily achieved by attempting to provide ways which shall be cylindrical within such limits, and the invention instead makes possible motion which is linear to such tolerances by means of the bearings 16 and 17. The ways 14 are required to be straight, i. e. their surface must conform accurately to the surface of a solid of revolution even of it falls short of a perfectly cylindrical figure. Such ways can be turned in a rigid lathe. Oil films between the ways and the bearings 16 and 17 can then be employed to adjust automatically for residual irregularities in the diameter of the ways.

In the bearing 16, at the right-hand end of the carriage 12 as shown in Fig. 1, a sleeve 61 is bored to have a very slight taper, of the order of .0001 inch per inch of length, and to have about .0005 inch average radial clearance from the ways 14. The large end of the taper is open in the direction of motion of the carriage during the working stroke. Thus during the working stroke the oil film on the ways is funneled into the bearing. The taper has been exaggerated in the figure for clarity. Lubrication forces make such a sleeve very stable especially during travel in the direction in which the large end of the taper leads. With a film 62 of lubricating oil of one or two poises viscosity on the ways, the sleeve 61, sliding at 2 feet per minute, suffers a centering force of about 2000 pounds for each .001 inch of radial displacement from a symmetrical position about the ways. It further suffers an aligning torque of 10 pounds-inches for each second of arc of angular displacement.

The sleeve 61 is connected to the carriage 12 by a ball and socket joint. A glass ball 63 having a spherical surface 65 conforming to a zone of a sphere with its center on the axis of the sleeve 61 is fitted to a socket member 67 to which the carriage is fastened. The ball 63 and socket 67 have their surfaces nicely fitted together by interferometric tests, and an interposed oil film 68 gives the combination enough rotational freedom to avoid jamming. The ball 63, suitably fastened to the sleeve 61 as by retaining rings 69, is held against the socket 67 by means of cantilever springs 71 affixed to the sleeve 61 at a collar 64 adjacent the end of the sleeve which leads during the working stroke. Three such springs for each bearing are usually sufficient.

The bearing 17 at the other end of the carriage may be identical with the bearing 16 except that the sense of taper of the sleeve is reversed with respect to the collar. In both bearings therefore the large end of the sleeve leads during the working stroke.

The cylindrical form of the ways 14 and the sleeve bearings which cooperate therewith greatly diminish the effect of wear in the ways on the accuracy of the rulings. Variations in the thickness of the oil films between the ways and the bearings will be symmetrical in the axis 15—15 and without effect on groove straightness. Similarly thermal expansion of the ways produced by friction with the sleeve bearings is symmetric about the axes 15—15.

The construction of the nuts and their relation to the screws 22 and to the surface being ruled is shown in Fig. 4. The nuts instead of embracing the screws throughout their circumference, include each four threaded pads 30, 31, 33 and 34 arranged on a frame member 35 so as to engage the screws only above and in the vicinity of the median plane thereof, i. e. only close to the plane defined by the screw axes 25—25 and 27—27. The use of nuts engaging the screws only in the vicinity of the horizontal median plane of the screws renders the rulings immune to sag of the screws since the lead of the screw threads in that plane is unchanged by elastic deflections associated with the sag of the screws.

On each nut, the threaded pads are arranged in pairs at the axial ends of the nut. All four pads are mounted on the frame so that their female threads conform to a single continuous helical thread. The two pads of each pair are preferably arranged on the frame so as to extend upwardly from the plane of the screw axes, and each pad subtends an angle at the axis of the screw of some 10 degrees. Arcs of contact of more than 20 degrees are undesirable since they result in engagement of the nut with the screw close to the top of the latter where the threads are deformed by sag of the screw. The nuts thus engage the screws over two arcs of the circumference of the screws, the arc of contact being separated by one arc (below) or not less than 180 degrees, and by another arc (above) of not less than 140 degrees.

The nuts grip the screws tightly when the screws are stationary because with engagement only in the vicinity of the horizontal median plane of the screws the radial forces between the nuts and screws must be high in order to provide a sufficient vertical component to carry the nuts and connector bar and diamond box.

Each nut is provided with a wing 46 extending transversely of the axis of the screw to which the threads of the pads 30, 31, 33 and 34 conform. A contact pad 106 on each of these wings is retained against the connector bar by a spring clip 107. Therefore a rotation of the screws in the direction which carries the screw surface on the wing side of the nut away from the connector bar (i. e. into the 180 degrees vacant arc) tends to draw down the wings. This is the direction of rotation given to the screws in pawling during the ruling process (counterclockwise as seen in Fig. 4). Conversely, retention of the wings against the connector bar by the clips 107 is accompanied by a loosening of contact between nut and screw which facilitates pawling and minimizes slip-stick friction errors in the displacement of the ruling tool. Both screws have threads of the same sense of rotation, so that the wings extend in the same direction transversely of the screws, as shown in Fig. 4.

The interconnections of the connector bar, nuts and screws are further shown in Fig. 5. The connector bar 36 which carries the ruling tool 37 in a diamond box 38 is supported by and between the nuts. Each nut has two contact pads 102 and 104 at the top of the frame 35 and at the axial ends of the nut, on which the weight of the connector bar rests (Fig. 4). The driver bearings or driving connections between the nuts and connector bar, determining the position of the bar and hence of the ruling tool in horizontal planes parallel to the plane of the screw axes, are provided by means of studs 110, one on each of the nuts. The studs 110 extend above the surface of the pads 102 and 104 and are received in apertures 111 formed in the underside of the connector bar. The studs extending into the apertures bear against bearing elements 112 in the walls of the apertures to transmit the thrust occasioned by advance of the nuts on the screws. The bearing surfaces of the elements 112 are oriented parallel to the long dimension of the connector bar and to each other, and are located on the side of the connector bar which leads during pawling of the screws.

The ruling tool is arranged to lie in a vertical plane passing through the driving connections. This plane is indicated at B_1—B_2 in Fig. 5. The ruling tool is further perferably disposed about halfway between the screws.

By virtue of the pivotal form of driving connection at the studs 110, drunkenness of the screw threads in horizontal planes will be without substantial effect on the motion of the connector bar since such drunkenness only rotates the nuts on their screws about vertical axes through the studs 110. Drunkenness in the vertical plane is likewise without substantial effect. Such drunkenness rotates the nuts about a horizontal axis in the planes of the screw axes at or close to the axial mid-point of the nuts. It is thus a rotation about an axis passing through a ruling tool.

If thickened oil films on the screws cause the nuts as a whole to rise, the result again is only a rotation of the nuts about vertical axes through their studs 110 without translation of the connector bar. Such lifting of the nuts does not therefore effect the position of the ruling tool on the grating blank.

By suitable disposition of the bearings 21 and 23 on the bed plate, the screws are arranged with their axes parallel and nearly, but not quite, perpendicular to the axis 15—15 which defines the direction of motion of the carriage. This departure from perpendicularity, though important, is too small to be shown in Fig. 1, and will be explained in connection with Fig. 5. The departure of the screw axes from perpendicularity to the line of motion of the carriage is measured by the helix angle of the path swept out around the axis of either screw by the stud 110 of its nut, considered as rotating about its screw. The departure is in such a sense as to bring this helical path of the studs at its highest point above the carriage into parallelism with the line of motion of the carriage, represented in Fig. 5 by the line 15′—15′, parallel to the axis 15—15 of the cylindrical carriage guiding ways.

With this disposition of the screws therefore the stud 110 of a nut rotated about a stationary screw will move at the top of its travel in a path parallel to the line of motion of the carriage. In the assembly of the engine, the position of one of the nuts on its screw is advanced by reference to the position of the other nut on the other screw to the extent required to bring the line B_1—B_2 connecting the studs 110 into parallelism with the axis 15—15, indicated in Fig. 5 by parallelism with the line 15′—15′. In Fig. 5 $B_{1'}$—$B_{2'}$ is the trace in a plane parallel to the plane of the screw axes of a vertical plane passing through the ruling tool at 37 and perpendicular to the screw axes. It is seen therefore that B_1—B_2 passing through the studs and through the ruling tool is not perpendicular to the screw axes.

This orientation of the driving connections between the nuts and the connector bar with respect to the screw axes renders the position of the ruling tool crosswise of the blank (i. e. perpendicularly to 15′—15′) immune to small shifts of the connector bar which may be caused by rotation of the nuts about the axes of their screws as a result of slip-stick friction between the screws and the nuts. For, such shifts will be along B_1—B_2, parallel to 15′—15′ and to the axis 15—15.

While a preferred embodiment of my invention has been shown in the drawings and described above, variations and modifications thereof may be made without departing from the invention as set forth in the appended claims.

I claim:

1. A ruling engine for the manufacture of diffraction gratings comprising a reciprocating carriage adapted to support a blank to be ruled, two screws journaled for rotation about parallel axes transverse to the direction of motion of the carriage, means to rotate the screws through constant increments of angle, a nut engaging each screw, and a ruling tool supported by and between the nuts.

2. A ruling engine for the manufacture of diffraction gratings comprising a reciprocating carriage adapted to support a blank to be ruled, two screws journaled for rotation about parallel axes above and transverse to the direction of motion of the carriage, means to reciprocate the carriage, means to rotate the screws through constant increments of angle in fixed phase with the reciprocation of the carriage, a nut engaging each screw, and a ruling tool supported by and between the nuts.

3. A ruling engine for the manufacture of diffraction gratings comprising a reciprocating carriage adapted to support a blank to be ruled, two screws journaled for rotation about parallel axes transverse to the direction of motion of the carriage and lying substantially in the plane of the surface of the blank to be ruled, a nut engaging each screw, and a ruling tool supported by and between the nuts with its point in the plane of the screw axes.

4. In a ruling engine having a reciprocating carriage for the support of a blank to be ruled and two screws journaled for rotation about parallel axes transverse to the direction of motion of the carriage, a nut engaging each of the screws, a connector bar supported by the nuts, and a ruling tool supported by the connector bar substantially in the plane of the screw axes.

5. In a ruling engine for the manufacture of diffraction gratings including a reciprocating carriage adapted to support a blank to be ruled, two screws journaled for rotation about parallel horizontal axes transverse to the direction of motion of the carriage, a nut engaging each screw, and a ruling tool supported by and between the nuts substantially in the plane of the screw axes: means to guide and support the carriage comprising two cylindrical ways having parallel collinear axes substantially in the plane of the screw axes, sleeve bearings connected to the carriage and engaging the cylindrical ways, auxiliary ways disposed on either side of the carriage, and shoes affixed to the carriage adapted to ride on the auxiliary ways, the bearings surfaces of the auxiliary ways lying substantially in the plane of the screw axes.

6. In a ruling engine for the manufacture of diffraction gratings including a reciprocating carriage adapted to support a blank to be ruled, two

screws journaled for rotation about parallel horizontal axes transverse to the direction of motion of the carriage, a nut engaging each screw, and a ruling tool supported by and between the nuts substantially in the plane of the screw axes: means to guide and support the carriage comprising two cylindrical ways having parallel collinear axes substantially in the plane of the screw axes, sleeve bearings connected to the carriage and engaging the cylindrical ways, auxiliary ways disposed on either side of the carriage, and shoes affixed to the carriage adapted to ride on the auxiliary ways, the bearing surfaces of the auxiliary ways lying substantially in the plane of the screw axes, said auxiliary ways supporting substantially the entire weight of the carriage.

7. In a ruling engine for the manufacture of diffraction gratings including a reciprocating carriage adapted to support a blank to be ruled, two screws journaled for rotation about parallel horizontal axes transverse to the direction of motion of the carriage, a nut engaging each screw, and a ruling tool supported by and between the nuts substantially in the plane of the screw axes: means to support and guide the carriage comprising a pair of parallel supporting ways disposed one on each lateral side of the carriage, shoes affixed to the carriage and adapted to ride on the supporting ways, two cylindrical ways having parallel collinear axes lying substantially in the plane of the screw axes, said cylindrical ways extending in opposite parallel directions from positions on remote sides of the screws, and sleeve bearings connected to the carriage and engaging the cylindrical ways.

8. In a ruling engine having a reciprocating carriage for the support of a blank to be ruled and a ruling tool advanced between strokes of the carriage by means of two screws transverse to the direction of motion of the carriage: nuts engaging the screws to support the ruling tool, each of said nuts comprising a resilient frame adapted to fit with clearance over the upper half of one of the screws and four threaded pads affixed to the frame in position to engage the thread of the screw over areas of the screw lying adjacent opposite ends of a diameter of the screw cross section.

9. In a ruling engine, a nut adapted to engage a precision screw for the traverse of a ruling tool between successive rulings, said nut comprising a frame adapted to fit over the screw, four threaded pads affixed to the frame in pairs at the axial ends of the frame, said pads being cut to conform to a single female thread matching the thread of the screw, said pads being further positioned to contact the screw over areas lying within arcs of the circumference of the screw separated by an arc of not less than 180 degrees on one side and by an arc of not less than 140 degrees on the other side.

10. An engine for the ruling of diffraction gratings comprising a reciprocating carriage for the support of a blank to be ruled, two screws supported above the carriage with their axes parallel and transverse to the line of motion of the carriage, means to rotate the screws in a given direction, a nut engaging each screw, a connector bar supported by the nuts, and a ruling tool supported by the connector bar, said nuts having threaded surfaces engaging the screws only above the median plane thereof, each of said nuts having a wing extending in a direction transverse of the screw axis for attachment to the connector bar, the sense of rotation of the screws being such that the force of friction between the screws and the nuts applies a torque between the nuts and connector bar tending to rotate the wings out of contact with the connector bar, whereby the friction between the nuts and the screws is reduced during rotation of the screws.

11. An engine for the ruling of diffraction gratings comprising a reciprocating carriage for the support of a blank to be ruled, two screws supported above the carriage with their axes parallel and transverse to the line of motion of the carriage, means to rotate the screws in a given direction, a nut engaging each screw, a connector bar resting upon the nuts, and a ruling tool supported by the connector bar, each of said nuts having threaded surfaces engaging its screw over two arcs of the screw circumference, said arcs being separated on one side by an arc of not less than 180 degrees and on the other side by an arc of not less than 140 degrees, each of said nuts having a wing extending in a direction transverse of the screw axis for attachment to the connector bar on the side of the nut from which the surface of the screw enters the 180 degree arc during rotation, whereby rotation of the screws reduces the friction between the screws and the nuts.

12. In a ruling engine including a pair of precision screws for traverse of a ruling tool between strokes of a carriage supporting the blank to be ruled beneath the tool, two bearings for each screw intermediate the ends thereof and a counterweight on each end of each screw outboard the bearings adapted to minimize the sag of the screws between the bearings.

13. A ruling engine for the manufacture of diffraction gratings comprising a reciprocating carriage adapted to support the blank to be ruled, two screws supported for rotation about parallel axes transverse to the direction of motion of the carriage, a nut engaging each screw, a connector bar pivotally linked to each of the nuts as regards motion in planes parallel to the plane of the screw axes, the line of centers of the pivots being inclined to the axes of the screws at the helix angle of the pivots, and a ruling tool supported from the connector bar.

14. In a ruling engine having a reciprocating carriage for the support of a blank to be ruled and a ruling tool advanced between strokes of the carriage by means of two screws: means to support the ruling tool comprising a nut engaging each of the screws, a connector bar supported by the nuts, and a driver bearing on each nut engaging the connector bar to define the position thereof in planes parallel to the plane of the screw axes, the ruling tool being supported from the connector bar substantially in the vertical plane between the driver bearings, the nuts being spaced on their respective screws to incline the line of centers of the driver bearings to the screw axes at an angle differing from a right angle by the helix angle of the paths of the driver bearings when rotated about the screws.

15. A ruling engine comprising a reciprocating carriage for the support of a blank to be ruled, two screws having threads of the same sense of rotation supported above the carriage with their axes parallel and transverse to the line of motion of the carriage, a nut engaging each screw, a connector bar supported by and between the nuts, a ruling tool supported by the connector bar, and a pivotal driver bearing on each of the nuts engaging the connector bar to define the position thereof in planes parallel to the plane of the screw axes, one of the nuts being advanced with respect to the other as required to bring the

line of centers of the driver bearings into parallelism with the projection onto the plane of the screw axes of the helical path about the screw axes of the driver bearings which would be traced by the nuts if rotated about the screws with the screws held stationary, the screws being mounted with their axes inclined to the line of motion of the carriage at an angle departing from 90 degrees by the inclination of the said helical path to a plane perpendicular to the screw axes, whereby the line of centers of the driver bearings is parallel to the line of motion of the carriage.

16. In a ruling engine for the manufacture of diffraction gratings including a reciprocating carriage adapted to support a blank to be ruled, two screws journaled for rotation about parallel horizontal axes transverse to the direction of motion of the carriage, a nut engaging each screw, and a ruling tool supported by and between the nuts substantially in the plane of the screw axes: means to support the carriage comprising two cylindrical guiding ways having collinear axes lying substantially in the plane of the screw axes, sleeve bearings connected to the carriage and engaging the cylindrical ways, supporting ways disposed on either side of the carriage, and shoes affixed to the carriage adapted to ride on the auxiliary ways, the bearing surfaces of the auxiliary ways lying substantially in the plane of the screw axes.

17. In a ruling engine for the manufacture of diffraction gratings including a reciprocating carriage for the support of a blank to be ruled and two cylindrical carriage-guiding ways: a bearing engaging each of the cylindrical ways adapted to guide the carriage in its motion, each of said bearings comprising a tapered sleeve adapted to fit over the cylindrical ways with a graduated clearance, said clearance being greatest at the end of the bearing which leads during the working stroke of the carriage, a ball bearing member affixed to the sleeve, a working surface on the ball bearing member conforming to a zone of a sphere coaxial with the sleeve, a socket bearing member affixed to the carriage, a working surface on the socket bearing member matching the working surface of the ball bearing member, and resilient means adapted to stress the ball and socket members together.

18. In a ruling engine for the manufacture of diffraction gratings including a carriage adapted to reciprocate a blank to be ruled under a ruling tool incrementally advanced crosswise of the direction of the rulings, means to reciprocate the carriage, and two cylindrical ways adapted to guide the carriage in its motion: a sleeve bearing coupling the carriage to each of the ways, each of said bearings comprising a sleeve adapted to fit over one of the cylindrical ways with an average clearance of the order of about .0005 inch, the sleeve having a taper of the order of .0001 inch per inch of length, a glass ball bearing member affixed to the sleeve, a working surface on the ball bearing member conforming to the surface of a sphere having its center on the axis of the sleeve, a socket bearing member affixed to the carriage, a working surface on the socket member matching the working surface of the ball bearing member, and a plurality of cantilever springs stressing the sleeve and socket members axially together.

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No references cited.