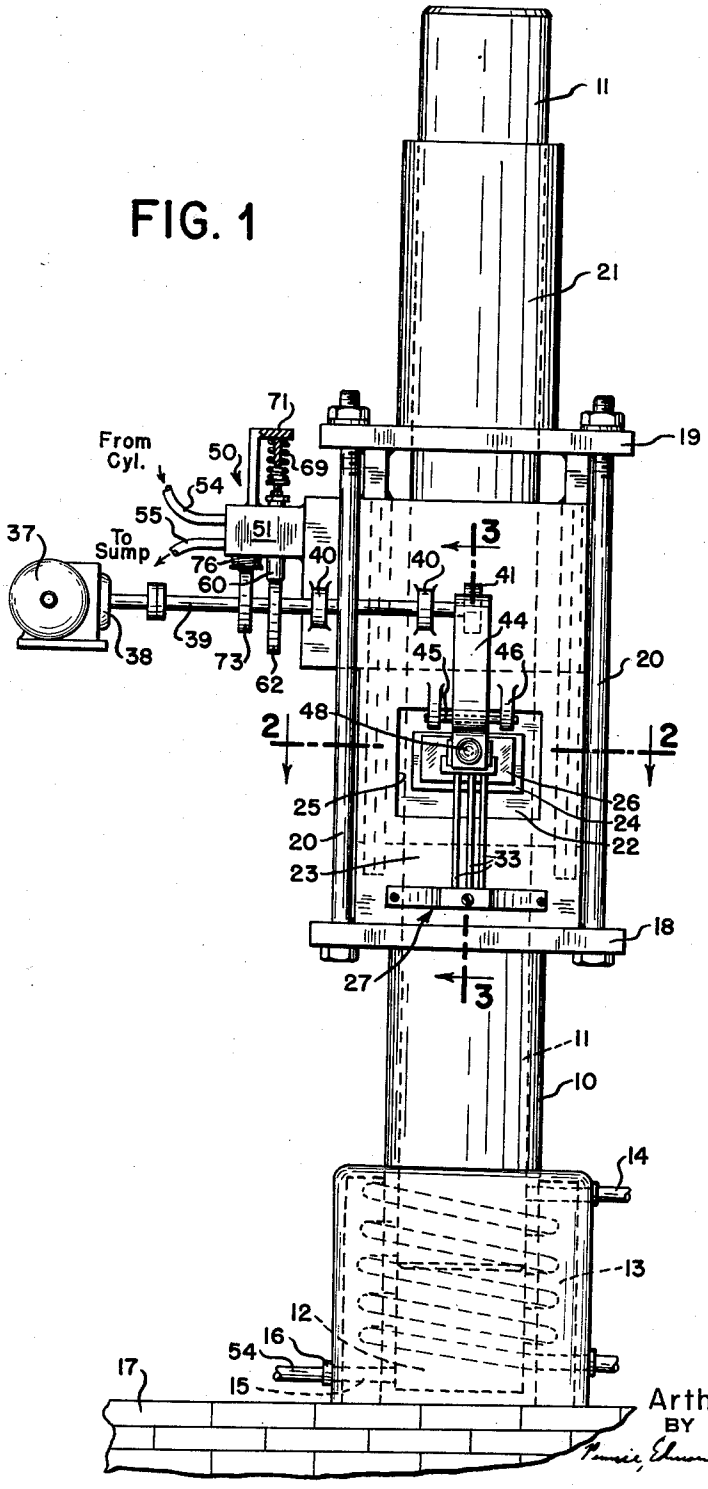
Oct. 29, 1963 A. H. AARON 3,108,379

MANUFACTURE OF DIFFRACTION GRATINGS

Filed March 14, 1962 3 Sheets-Sheet 1

FIG. 1



INVENTOR
Arthur Harry Aaron
BY
Pennie, Edmonds, Morton, Barrow & Taylor
ATTORNEYS

Oct. 29, 1963 A. H. AARON 3,108,379

MANUFACTURE OF DIFFRACTION GRATINGS

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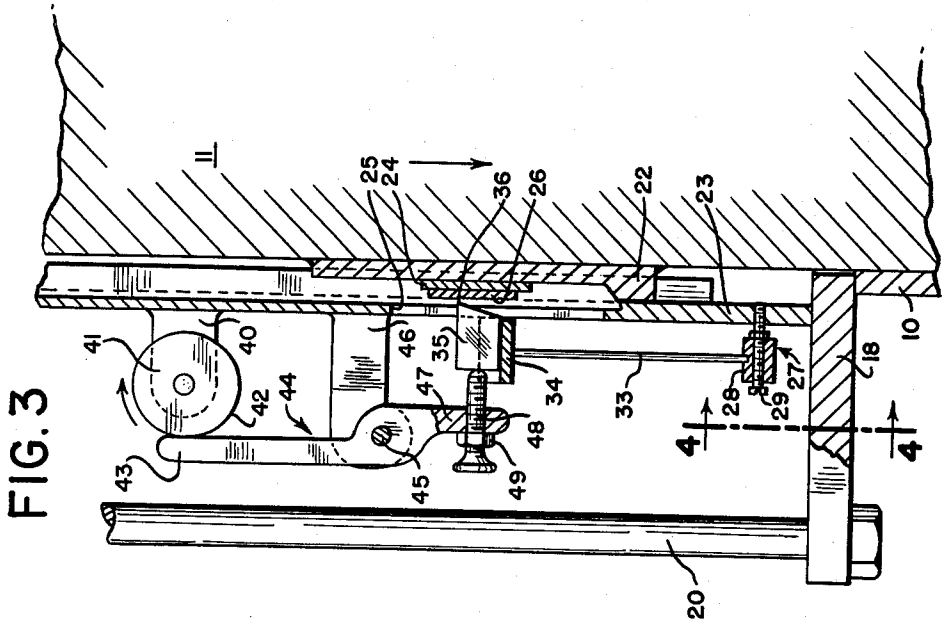


FIG. 3

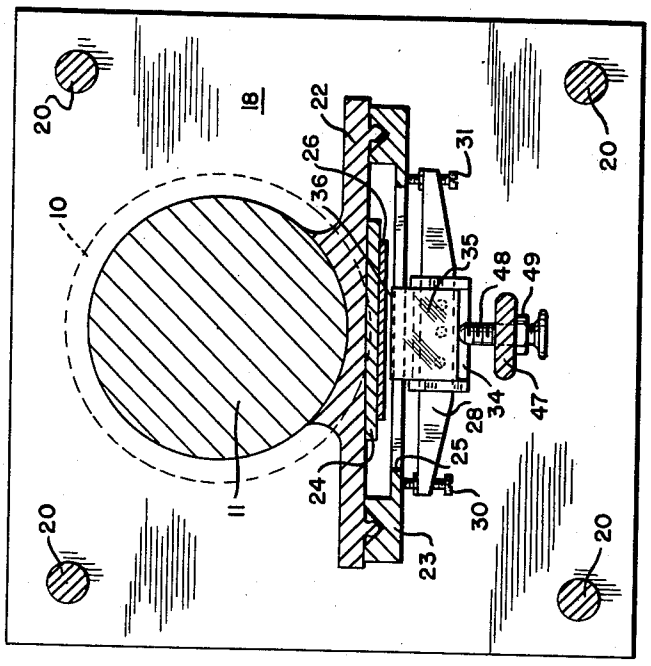


FIG. 2

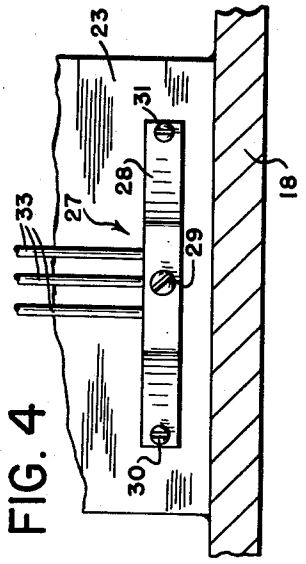


FIG. 4

INVENTOR
Arthur Harry Aaron
BY
Pennie, Edmonds, Morton, Barrow & Taylor
ATTORNEYS

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MANUFACTURE OF DIFFRACTION GRATINGS

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FIG. 9

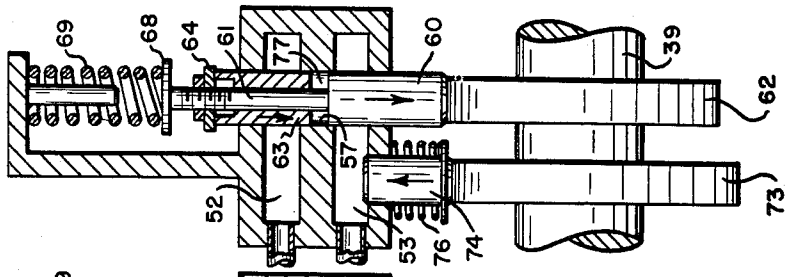


FIG. 8

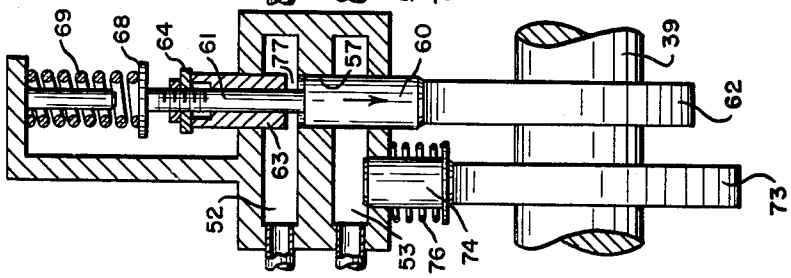


FIG. 7

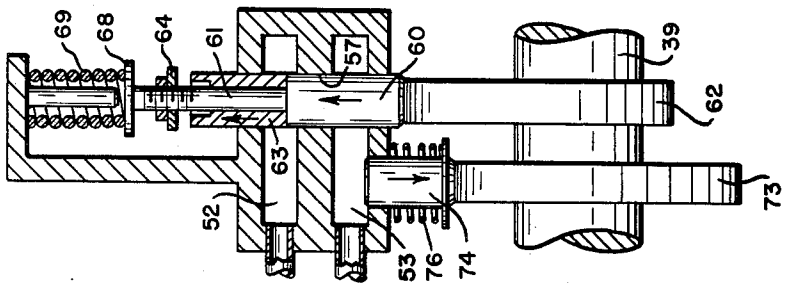


FIG. 6

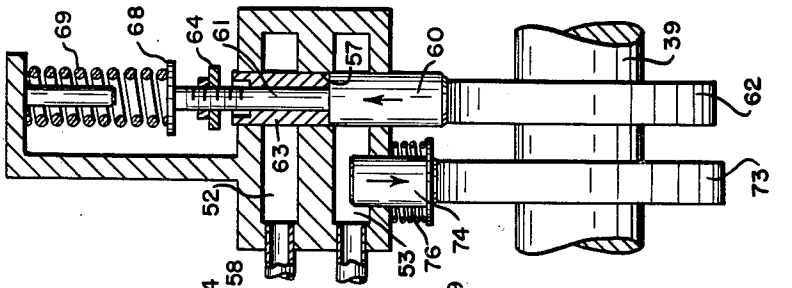
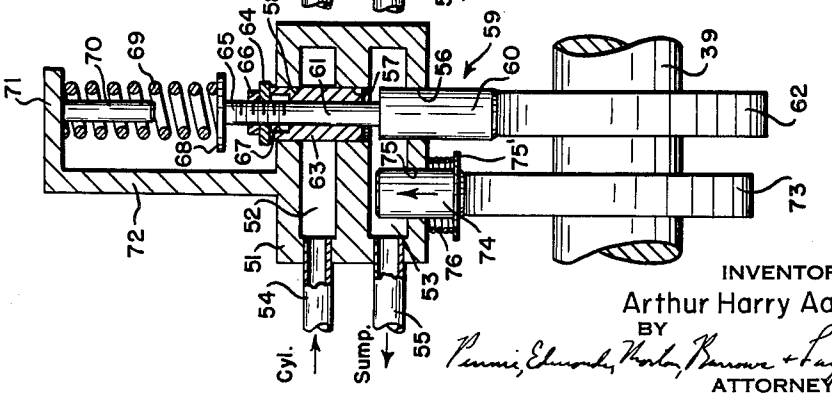


FIG. 5



INVENTOR
Arthur Harry Aaron
BY
Pennie, Edmonds, Morton, Barrows & Taylor
ATTORNEYS

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3,108,379

MANUFACTURE OF DIFFRACTION GRATINGS

Arthur Harry Aaron, 527 Lexington Ave.,
New York, N.Y.

Filed Mar. 14, 1962, Ser. No. 179,673
12 Claims. (Cl. 33—19)

This invention concerns the manufacture of diffraction gratings in which a multiplicity of closely spaced parallel lines are precisely marked on an optically flat workpiece. More particularly, the invention relates to a new method and apparatus for making diffraction gratings characterized by improvements in the design and operation of the marking tool and in the means for indexing the workpiece relative to the tool.

Diffraction gratings are used in spectroscopes to disperse light into its various wave lengths. They consist of an optically flat plate of specially manufactured quartz coated on one face with a thin film of aluminum in the range of about one ten-thousandth of an inch thickness. This aluminum layer is ruled with a multiplicity of fine parallel lines, identical in cross section and uniformly spaced, and as many as one to forty thousand or more such lines may be marked on each linear inch of the grating. The aluminum is not removed at the ruled lines but is rather displaced at its surface so that the glass base remains covered. To a great extent, the quality of any diffraction grating is determined primarily by the number and uniformity of lines per inch marked on it.

Apparatus for marking the lines on a diffraction grating is referred to in the art as a ruling engine. Only a very few have been made which meet the extraordinary standards of precision necessary to produce satisfactory gratings, and some of these have been in use for decades. Heretofore, it has been a cardinal principle in the design of ruling engines that the indexing means for displacing the workpiece relative to the tool from one line to the next must be built around a fine screw-type drive shaft; no successful ruling engine ever made prior to the present invention has departed from this. The theory has been that only a screw is capable of ruling every groove on the diffraction grating in an exactly spaced relation to the very first one ruled; which is to say, only a screw is theoretically free of cumulative error as it indexes the workpiece relative to the tool. It has also been the universal practice heretofore to use a diamond needle as the marking tool, in a manner such that the tool slides back and forth relative to the workpiece to scribe the necessary faint lines in the surface of the aluminum film.

Geometrical perfection is the ideal in ruling diffraction gratings and of course it is impossible. It is the primary purpose of this invention to provide a new method and apparatus for marking lines on a grating which approaches substantially closed to that theoretical standard than any currently available. I have achieved this by departing essentially from the use of a screw-type drive shaft as the heart of the indexing means and of a sliding needle as the marking tool and turning instead to novel indexing and marking means which avoid the inherent disadvantages of their conventional counterparts.

The basic shortcoming of a screw-type indexing means is that discontinuity of operation is always present to some extent as a result of friction, wear, warpage, creep, vibration, dust and temperature changes. The latter three cannot satisfactorily be avoided except by operation of the ruling engine in a carefully controlled attenuated environment. Friction and wear are factors which always exist in a ruling engine in proportion to the extent of its contacting surfaces which move relative to one another, and the screw-type of apparatus is notoriously vulnerable to them because of its considerable interfaces which

slide one upon the other with substantial bearing force. Warpage and creep can be precluded entirely only by the use of perfectly rigid and hard materials. This being impossible, the most advantageous design is one in which the primary parts of the ruling engine are isolated from sustained stress concentrations, and again the conventional drive screw form is far from the ideal because of the high bending forces exerted between its bearing points and the considerable creep stresses on the ways which support the indexing carriage.

It is an inherent defect in the design of needle-type marking tools for ruling engines that they undergo microscopic yet serious oscillation during their sliding stroke which produces a waver in the lines marked on the grating. One of the more important objects of my invention is to eliminate all such sliding contact between the tool and the workpiece which heretofore has been the source of this wavering.

Broadly stated, my invention concerns precision apparatus for marking a multiplicity of fine closely spaced parallel lines on a flat workpiece by means of a marking tool. The improvement comprises a substantially vertical cylinder and axial translatable piston defining a chamber for containing fluid. Extending from this cylinder is a portion of the piston which supports either the tool or the workpiece; a frame supports the other of the tool or workpiece. The flat of the workpiece is vertical. There is provided a movable tool for defining a straight knife edge transverse to the piston axis in opposition to the flat of the workpiece. Displacement means are included for effecting relative movement of this knife edge into and out of marking engagement with the workpiece flat without relative sliding therebetween. Piston indexing means are provided for periodically changing the volume of a fluid in the chamber to effect a predetermined axial displacement of the piston, whereby the workpiece is relatively displaced transverse to the edge of the tool. The displacement and indexing means are actuated by synchronized driving means which effect engagement of the tool knife edge and workpiece flat at a time when the piston is stationary.

In a preferred form of this new ruling engine, the tool displacement means comprises at least one bendable self-supporting rod fixed at one end and supporting the tool at its other end. This rod is disposed at least substantially vertical. Means are provided for nodding the tool on the rod and displacing the knife edge thereof into and out of the abovementioned non-sliding engagement with the workpiece flat. The preferred form of the piston indexing means includes a casing defining a well in communication with a fluid-filled chamber. Metering means slidable in sealing engagement into and out of this well are adapted to extract therefrom a predetermined volume of fluid at each outward stroke. Cam means are provided engaging this plunger means to displace it into and out of the space.

The invention also provides a novel method for making diffraction gratings wherein a multiplicity of fine closely spaced parallel lines are marked on an optically flat workpiece. The steps of the new method comprise normally limiting the movement of the workpiece in a downward direction by pressurization by a contained body of fluid, and moving a straight knife edge toward the flat of the workpiece in a direction transverse to that edge. Simultaneous line contact is then made between the flat and all points along the straight knife edge without sliding the knife edge relative to the flat, thereby marking a line on the flat. Next, all points along the knife edge are withdrawn simultaneously in relation to the flat again without sliding the knife edge relative to the flat. The volume of the body of fluid is then changed a predetermined amount so that the workpiece is indexed in that

downward direction in which movement thereof is otherwise limited. The foregoing sequence of steps is then repeated.

In accordance with the method and apparatus of the invention, the workpiece may be displaced relative to the tool from one marked line to the next without appreciable error. This is so because the relative indexing movement of the workpiece is a function solely of the precision by which a predetermined volume of fluid is extracted from the cylinder beneath the piston. This volume remains unchanged from one cycle to the next in the new design, and hence there is no cumulative error. All substantial forces on the piston act in a vertical direction and are limited to the compression forces of the piston's own weight. Once the machine has been properly broken in and initial warpage and creep (if any) have taken place, no change will occur in the critical dimensions of the device because these major operating forces remain compressive and unidirectional under all circumstances. Friction and wear are entirely eliminated as factors adverse to the dimensional stability of the structure because they exist only at minor sliding interfaces at which there is little or no bearing force.

The knife edge of the new tool impresses a fine line into the aluminum coating on the workpiece in a single in-and-out marking motion entirely free of sliding contact between it and the workpiece. Therefore, wavering of the tool is non-existent and the quality of the ruled line is a function largely of the straightness of the knife edge; experience has established that tools can be made up to several inches in length which are entirely satisfactory in straightness and uniformity for marking diffraction gratings. Also, the nodding action of the tool on its three bendable supports may be repeated many tens of thousands of times without significant change in the form of the ruled lines.

Diffraction gratings manufactured in accordance with this invention are of a quality equal to or superior to any now made and, most importantly, they can be made in enlarged sizes and in repeated numbers without any critical variation in form and dimensions. This considerable advance in the art of ruling engines is achieved by an essential departure from screw-type indexing and needle-type marking tools which have been beset with such serious dimensional problems heretofore.

The following is a description of a preferred embodiment of the invention with reference to the accompanying drawings, wherein

FIG. 1 is an elevation of the new ruling engine;

FIG. 2 is an enlarged horizontal section taken along the line 2—2 of FIG. 1;

FIG. 3 is an enlarged fragmentary vertical section taken along the line of 3—3 of FIG. 1;

FIG. 4 is an enlarged fragmentary section taken along the line of 4—4 of FIG. 3;

FIG. 5 is an enlarged fragmentary section of the valving device associated with the new indexing means, showing it in its initial or retracted position;

FIG. 6 is a view similar to FIG. 5 showing the valving device moving toward its inserted position;

FIG. 7 is a view similar to FIG. 5 showing the valving device in its inserted position;

FIG. 8 is a view similar to FIG. 5 showing the valving device moving away from its inserted position; and

FIG. 9 is a view similar to FIG. 5 showing the valving device returning to its initial retracted position.

In FIG. 1, the new ruling engine is shown to include a cylinder 10 and an associated piston 11 adapted to slide therewithin with suitable gasketing around it. The cylinder 10 is vertically disposed and closed at its bottom and open at its top such that the piston 11 extends upwardly. The exposed upper portion of piston 11 is considerably greater in length than its lower end portion projecting downwardly into the cylinder. Together the cylinder 10 and piston 11 define a chamber 12 filled completed with a hydraulic oil. Advantageously, the piston is of solid metal perhaps about four inches in diameter and several feet long, so that its own weight pressurizes this oil-filled chamber. The chamber 12 is surrounded by a temperature controlling jacket 13 through which a coolant is circulated by means of a suitable conduit 14. The only outlet from the chamber 12 is through a bore 15 leading to a fitting 16 at the base of the cylinder 10. A solid foundation 17 is provided for the entire engine.

At the upper end of the cylinder 10 is a flat annular horizontal plate 18 which is spaced rigidly from a corresponding upper plate 19 by means of four large connecting bolts 20. The upper plate 19 supports an elongated guide bushing 21 through which the upper end portion of the piston 11 moves. It is important that the axes of the bushing 21 and cylinder 10 correspond exactly so that the piston 11 may be translated along a common axis at both ends.

As shown more clearly in FIG. 2, the exposed portion of the piston 11 between the lower and upper plates 18 and 19 supports a vertical platen 22 arranged with its flat parallel to the piston axis. Though the platen 22 is securely affixed to the piston 11, it is further guided in its movement with the piston by means of a frame 23 disposed between the platen and the two connecting bolts 20 on the front of the engine. Suitable attachment is made between the lower and upper ends of the frame 23 to the plates 18 and 19. It is to be noted that the sliding interfaces between the frame 23 and the platen 22 function solely as vertical guides and are not ways in the ordinary sense of horizontal sliding supports. Little bearing force, and consequently minimal friction and wear, is created between the frame 23 and platen 22.

Referring now to each of FIGS. 1–3, a base plate 24 is attached securely to the vertical face of the platen 22 in such a manner that the outermost plane of the base plate 24 is exactly plumb and parallel to the piston axis. A window 25 is formed in the frame 23 so that access may be had to the base plate 24 even when the piston 11 moves axially several inches. The workpiece 26, i.e. a piece of optically flat special quartz coated with aluminum on which lines are to be ruled, is attached by any suitable means known in the art to the center of the base plate 24, in a manner such that the coated outward surface of the workpiece is vertical.

Beneath the window 25 of the frame 23 is an adjustable support 27 shown most clearly in FIGS. 3 and 4. It consists of bar 28 pivoted at its center to the frame 23 by means of a screw 29. Locking screws 30 and 31 are threaded through the opposed ends of the bar 28 into abutment with the frame 23. By this construction the bar 28 may be turned in a vertical plane about the screw 29 and locked in any given position. Three bendable yet self-supporting rods 33 extend vertically from the upper surface of the bar 28 and support a standard 34 at their upper ends as shown in FIG. 3. A marking tool 35 is releasably adhered or otherwise attached to the standard 34 with the working end of the tool projecting through the window 25 in the frame 23 directly opposite the workpiece 26. This adjustable support 27 for the tool 35 permits it to be disposed horizontally in opposition to the workpiece 26. In the rest position of the tool 35, its working end is spaced very close to the aluminum-coated outer face of the workpiece, perhaps ten to twenty thousandths of an inch, and the three supporting rods 33 are substantially vertical.

The new marking tool is shown in FIGS. 2–4. It may be made of high-carbon tool steel or other hard material. At its working end, it has an exactly straight horizontal knife edge 36 defined by its upper flat surface and an angular face bevelled at approximately fifteen degrees. The length of the knife edge 36 determines the length of the lines ruled on the workpiece. When the tool 35 is moved forward into marking engagement with the workpiece, all points along the knife edge 36 make simultaneous contact

with the aluminum-coated surface of the workpiece, and they are withdrawn simultaneously in the same manner when the knife edge 36 is retracted. No sliding action whatsoever occurs between the tool 35 and the workpiece; there is only an inward and outward precise indenting motion which marks the entire line at one instant without any wavering whatsoever. The straightness of the marked line is therefore determined largely by the straightness of the cutting edge, which can be made sufficiently true to meet the exacting standards of this art, and identity of linear form and cross section of successive lines is guaranteed.

The tool 35 is moved into and out of marking contact with the workpiece by a force exerted on its end opposite the knife edge 36. This causes the rods 33 to nod very slightly toward the piston so that the tool is allowed to move forwardly. Total displacement of the knife edge may be only about two to six thousandths of an inch, and so this bending movement of the rods 33 is almost indiscernible. Their inherent resiliency brings them back to upright position after the actuating force has been released from the tool. It has been found that this working cycle of the tool may be repeated many tens of thousands of times without variation in the marking action of the knife edge 36.

FIGS. 1 and 3 show the displacement means by which the tool 35 is nodded inwardly and outwardly. A constant speed electric motor 37 is mounted stationary with respect to the ruling engine alongside it at a sufficient distance to insure that heat radiated from the motor has no adverse thermal effect on the other parts of the engine. The speed of the motor 37 is stepped down to about one hundred r.p.m. by a suitable gear reducer 38 connected to a master drive shaft 39. The shaft 39 is journaled at 40 to the frame 23 and extends horizontally across the frame 23.

At its outer end the shaft 39 supports a first cam 41 disposed in a vertical plane directly over the tool 35. As shown in FIG. 3, the cam 41 may have a somewhat isolated land 42 on its periphery or it may be formed more eccentrically, but in any event it has a considerable dwell period. As the cam 41 rotates, it engages the outer end of an arm 43 on a rocker 44 and cyclically pivots the rocker about a horizontal shaft 45 journaled between bearings 46 on the plate 23. An arm 47 extends from the opposite end of the rocker 44 and has an adjustable finger 48 screw-threaded normally therethrough. A lock nut 49 is provided to locate the position of the finger 48 firmly with respect to the rocker 44. At its inner end, the finger 48 is rounded and abuts that vertical surface of the tool 35 remote from the knife edge 36. Whenever the land 42 on the cam 41 displaces the arm 43 of the rocker 44, the tip of the finger 48 moves slightly in a counterclockwise direction as seen in FIG. 3 to urge the tool 35 forward firmly but gently in its marking direction. By suitably hardening the tip of the finger 48 and the opposite contact surface of the tool 35. This displacement means may operate many tens of thousands of cycles without dimensional variation. The bending forces which nod the rods 33 forward are relatively slight and the total displacement of the tool is so fine that no appreciable friction or wear occurs in the parts of this mechanism nor do the resilient rods undergo plastic deformation.

In FIG. 1, a valving device 50 is shown rigidly affixed to the frame 23 on the left of the apparatus and it appears in detail in FIG. 5. The valving device 50 includes a casing 51 in which is defined two wells 52 and 53; the well 52 communicates solely with the fitting 16 leading to the chamber 12, through a conduit 54, and the well 53 communicates solely with a sump (not shown) through a conduit 55. Extending completely through the casing 51 is a straight bore consisting of a first portion 56 through the outer wall of the well 53, a second portion 57 through the intermediate wall between the wells 52 and 53, and a third portion 58 through the outer wall of the well 52.

A metering device indicated generally by the numeral 59 extends in sliding contact through these three portions 56–58 of the bore. Suitable gasket means are located at each of the three bore portions to insure that no leakage of fluid can occur between the metering device 59 and the casing 51, though for purposes of simplicity such gaskets are not shown in the drawings. The metering device 59 includes a plunger 60 of circular cross section from which a coaxial circular post 61 extends at one end. At its other end, the plunger engages an eccentric cam 62 affixed to the master drive shaft 39 driven by the motor 37, as described previously. Surrounding the post 61 is an elongated collar 63 exactly equal in cross section to the plunger 60. The collar 63 is slidable on the post 61 between the plunger 60 and a stop element 64 which is selectively located on a threaded portion 65 of the post 61 by means of a lock nut 66. A counterbore 67 is formed in the end of the elongated collar 63 to prevent interference with the threaded portion 65 of the post. At the end of the post opposite the plunger 60 is an enlarged flat head 68 against which is biased a compression spring 69. The spring 69 surrounds a guide 70 and is contained at its opposite end by a flange 71 on a bracket 72 extending rigidly from the casing 51.

In addition to the cam 62 there is also located on the drive shaft 39 adjacent the valving device 50 another eccentric cam 73 which is in sliding engagement with a primer 74. The primer 74 extends through a short bore 75 in the outer wall of the well 53, again with suitable gasket means (not shown) to preclude leakage. A flange 75' surrounds the primer 74 at its outer end portion and a compression spring 76 is biased between this collar and the casing 51 to urge the primer outwardly.

It is the purpose of this valving device 50 to extract cyclically a precise volume of fluid from the chamber 12 between the cylinder 10 and the piston 11. Because of the weight of the piston 11 on this chamber 12, the hydraulic fluid therein is forced up through the conduit 54 and into the well 52 of the valving device. The initial position of the valving device before it commences its extracting stroke is shown in FIG. 5. At that point, the plunger 60 is spring-biased into its lowermost position such that its upper end is withdrawn from the bore portion 57. The elongated collar 63 is also at its lowermost position, urged there by the stop 64 on the post 61, such that its lower end is just inside the bore portion 57 and spaced from the plunger 60. The primer 74 at this point is in its uppermost position extending into the well 53, and its spring 76 is compressed. There is a considerable dwell period on each of the cams 62 and 73, so that this position shown in FIG. 5 is maintained for a relatively long time. During this dwell, shaft 39 rotates and effects the marking motion of the tool 35 on the workpiece.

After the workpiece has been marked as described previously, the cam 62 begins moving the plunger 60 upwardly and the primer 74 downwardly relative to the casing 51. Thus, the plunger 60 moves up against the compression spring 69 and closes the gap between it and the elongated coller 63 so that the two move in end-to-end engagement as shown in FIG. 6. The primer 74 meanwhile moves downwardly out of the well 53.

As this inward movement of the metering device occurs, the plunger 60 moves through the bore portion 57 so that the interface between it and the elongated collar 63 enters the well 52 communicating with the chamber 12. This continues to the point of fullest insertion shown in FIG. 7, at which time the spring 69 is at its maximum compression. The primer 74 meanwhile withdraws into its lowermost position in the bore 75 out of the well 53 communicating with the sump.

Then the metering device 59 begins its travel in the reverse downward direction. As shown in FIG. 8, the compression spring 69 urges the post 61 and the plunger

60 downwardly but the elongated collar 63 does not initially move with them because of the frictional resistance of the gasketing in the bore portion 58. Only when the stop 64 abuts the end of the collar 63 as shown in FIG. 8 does the collar begin to move also, and by that time a gap 77 has been opened between the plunger 60 and the collar 63. The primer 74 meanwhile dwells in its withdrawn position.

Once the stop 64 has picked up the collar 63, the latter moves with the plunger 60 so that the gap 77 moves downwardly into the bore portion 57 to take with it an annular volume of hydraulic fluid from the well 52. This annular volume in the gap 77 is pulled through the bore portion 57 as shown in FIG. 9, and during that time the primer 74 begins moving upwardly into the well 53.

Finally, the cam 62 allows the spring 69 to force the metering device 59 back to its initial position shown in FIG. 5 where the plunger 60 is withdrawn from the bore portion 57 so that the gap 77 communicates with the well 53. The volume of hydraulic liquid thus deposited in the space 53 is pushed therefrom through the conduit 55 leading to the sump by means of the primer 74, which by then has reached its fullest inserted position.

By these means, an exact amount of hydraulic fluid, equal to the volume of the annular space in the gap 77, is extracted from the cylinder 12 at each cycle between marking strokes of the tool 35. Suitable gasketing of the bores in the casing 51 entirely prevents leakage in this sequence of operation and the piston 11 indexes the workpiece 26 precisely from one marked line to the next. Any minute variations in the amount of liquid cyclically withdrawn is well within the close tolerance required for high-quality diffraction gratings because only a slight change in the thickness of the gap 77 could be responsible for such variation, and that total thickness is enormous compared to the microscopic displacement of the relatively large diameter piston 11. Many tens of thousands of cycles of this valving device 59 can be carried out without significant change in the indexing of the workpiece.

The new ruling engine is capable of marking as much as fifty thousand lines per inch or more on a workpiece at a rate in the order of one hundred lines per minute. This performance is superior to that of the best of the ruling engines now in existence. Also, the quality and uniformity of the ruled lines made by the present device is markedly superior because of the instantaneous non-wavering indentation of a complete line by the new straight-edge tool. The indexing means for the workpiece undergoes the same action of forces, both in value and direction, regardless of the work position and hence there is almost perfect displacement of the workpiece between each marked line. There are no substantial bearing forces at any of the sliding interfaces in the new ruling engine and as a result friction and wear are both at an almost irreducible minimum. Moreover, there are no substantial bending forces acting upon the workpiece carrier (only forces in compression resulting from the weight of the piston 11) and consequently there is little warpage or creep of any parts during prolonged operation of the apparatus. Because a master drive shaft actuates both the indexing means and the tool displacement means, there is no chance of discrepancy between the spaced lines due to an early or late marking stroke of the tool 35 in relation to the displacement stroke of the piston 11.

I claim:

1. In precision apparatus for marking a multiplicity of fine closely spaced parallel lines on a flat workpiece by means of a marking tool, the improvement which comprises:

(*a*) a substantially vertical cylinder and axially translatable piston defining a chamber for containing fluid,

(*b*) a portion of said piston extending from said cylinder and supporting one of said tool and workpiece,

(*c*) a frame supporting the other of said tool and workpiece,

(*d*) the flat of said workpiece being vertical,

(*e*) a movable tool defining a straight knife edge transverse to the piston axis in opposition to the flat of said workpiece,

(*f*) displacement means for effecting relative movement of said knife edge into and out of marking engagement with the workpiece flat without relative sliding therebetween,

(*g*) piston indexing means for periodically changing the volume of fluid in said chamber to effect a predetermined axial displacement of said piston, whereby said workpiece is relatively displaced transverse to the edge of said tool, and

(*h*) synchronized driving means for actuating said displacement and indexing means to effect engagement of the tool knife edge and workpiece flat at a time when said piston is stationary.

2. Precision apparatus for marking a multiplicity of fine closely spaced parallel lines on a flat workpiece comprising:

(*a*) a vertical cylinder and axially translatable piston defining a chamber for containing fluid,

(*b*) a portion of said piston extending upwardly from said cylinder and adapted to support said workpiece with the flat thereof vertical,

(*c*) a movable tool defining a straight knife edge transverse to the piston axis in opposition to that part of said piston adapted to support said workpiece,

(*d*) tool displacement means for moving said knife edge into and out of marking engagement with the workpiece flat without relative sliding therebetween,

(*e*) piston indexing means for periodically changing the volume of fluid in said chamber to effect a predetermined axial displacement of said piston, whereby said workpiece is displaced transverse to the edge of said tool, and

(*f*) synchronized driving means for actuating said tool displacement means and said piston indexing means to effect said engagement of the tool knife edge and workpiece flat at a time when said workpiece is stationary.

3. Precision apparatus for making diffraction gratings wherein a multiplicity of fine closely spaced parallel lines are marked on a flat workpiece comprising:

(*a*) a vertical hydraulic cylinder and axially translatable piston defining a chamber for containing liquid,

(*b*) said piston being continuously urged against said liquid,

(*c*) a portion of said piston extending from said cylinder and adapted to support said workpiece with the flat thereof vertical,

(*d*) a movable tool defining a horizontal straight knife edge in opposition to that part of said piston adapted to support said workpiece,

(*e*) tool displacement means for moving said knife edge into and out of marking engagement with the workpiece flat without relative sliding therebetween,

(*f*) piston indexing means for periodically reducing the volume of liquid in said chamber to effect a predetermined axial displacement of said piston, whereby said workpiece is displaced perpendicular to the edge of said tool, and

(*g*) a common drive shaft for actuating said tool displacement means and said piston indexing means to effect said engagement of the tool knife edge and workpiece flat at a time when said piston is stationary.

4. Precision apparatus for making diffraction gratings wherein a multiplicity of fine closely spaced parallel lines are marked on an optically flat workpiece comprising:

(*a*) a vertical cylinder and axially translatable piston defining a chamber for containing a hydraulic liquid,

(b) a portion of said piston extending upwardly from said cylinder,
(c) said piston being urged downwardly into said cylinder by gravity,
(d) a platen affixed to said upwardly extending portion of said piston and adapted to support said workpiece with the flat thereof vertical,
(e) a tool defining a horizontal straight knife edge in opposition to said platen,
(f) at least one bendable self-supporting substantially vertical rod fixed at one end and supporting said tool at the other end,
(g) displacement means for nodding said tool on said rod and displacing the knife edge thereof into and out of marking engagement with the workpiece flat without relative sliding therebetween,
(h) piston indexing means for periodically changing the volume of liquid in said chamber to effect a predetermined axial displacement of said piston, whereby said workpiece is displaced vertically, and
(i) a common drive shaft for actuating said displacement means and said piston indexing means to effect said engagement of the tool knife edge and workpiece flat at a time when said piston is stationary.

5. Precision apparatus for making diffraction gratings wherein a multiplicity of fine closely spaced parallel lines are marked on an optically flat workpiece comprising:
(a) a vertical closed-bottom open-top cylinder and axially translatable piston defining a chamber for containing a hydraulic liquid,
(b) a portion of said piston extending upwardly from said cylinder,
(c) a temperature-controlling jacket surrounding said chamber,
(d) said piston being urged downwardly into said cylinder by gravity,
(e) a platen affixed to said upwardly extending portion of said piston and adapted to support said workpiece with the flat thereof vertical,
(f) a tool defining a horizontal straight knife edge in opposition to said platen,
(g) a plurality of bendable self-supporting vertical rods fixed at one end and supporting said tool at their other end,
(h) a drive shaft rotatable about an axis stationary relative to said cylinder,
(i) a rocker pivotally mounted about an axis stationary relative to said cylinder and engageable at one end with said tool,
(j) a cam on said drive shaft engaging the other end of said rocker for nodding the knife edge of the tool on said rods into and out of marking engagement with the workpiece flat without relative sliding therebetween,
(k) piston indexing means for periodically reducing the volume of liquid in said chamber to effect a predetermined axial displacement of said piston, whereby said workpiece is displaced vertically, and
(l) a common drive shaft for actuating said cam and said piston indexing means to effect said engagement of the tool knife edge and workpiece flat at a time when said piston is stationary.

6. Precision apparatus for marking a multiplicity of fine closely spaced parallel lines on a flat workpiece comprising:
(a) a vertical cylinder and axially translatable piston defining a chamber for containing fluid,
(b) a portion of said piston extending from said cylinder and adapted to support said workpiece with the flat thereof at least substantially vertical,
(c) a movable tool defining a straight knife edge transverse to the piston axis in opposition to that part of said piston adapted to support said workpiece,
(d) tool displacement means for moving said knife edge into and out of marking engagement with the workpiece flat without relative sliding therebetween,
(e) piston indexing means for periodically reducing the volume of fluid in said chamber to effect a predetermined axial displacement of said piston, whereby said workpiece is displaced vertically comprising:
(1) a casing defining a well in communication with said chamber,
(2) metering means slidable in sealing engagement into and out of said well and adapted to extract therefrom a predetermined volume of fluid at each outward stroke, and
(3) cam means engaging said metering means to displace it into and out of said well, and
(f) synchronized drive means for actuating said tool displacement means and cam means to effect said engagement of the tool knife edge and workpiece flat at a time when said piston is stationary.

7. Apparatus according to claim 6 wherein said piston indexing means comprises:
(1) a casing defining a well in communication with said chamber and having a bore extending therethrough into said well,
(2) a plunger slidable in sealing engagement in said bore from a retracted position withdrawn from said bore to an inserted position extending through said bore and into said well,
(3) a post extending longitudinally from that end of said plunger insertable into said well,
(4) an elongated collar coaxial with and equal in cross section to said plunger and slidable on said post a limited distance less than the length of said bore,
(5) said plunger being biased toward said retracted position, and
(6) an eccentric cam on said drive shaft engaging said plunger to displace it between said retracted and inserted positions.

8. Precision apparatus for making diffraction gratings wherein a multiplicity of fine closely spaced parallel lines are marked on an optically flat workpiece comprising:
(a) a vertical closed-bottom open-top cylinder and axially translatable piston defining a chamber for containing a hydraulic liquid,
(b) a portion of said piston extending upwardly from said cylinder,
(c) a temperature-controlled jacket surrounding said chamber,
(d) said piston being urged downwardly into said cylinder by gravity,
(e) a platen affixed to said upwardly extending portion of said piston and adapted to support said workpiece with the flat thereof vertical,
(f) a tool defining a horizontal straight knife edge in opposition to said platen,
(g) a plurality of bendable self-supporting vertical rods fixed at one end and supporting said tool at their other end,
(h) a drive shaft rotatable about an axis stationary relative to said cylinder,
(i) a rocker pivotally mounted about an axis stationary relative to said cylinder and engageable at one end with said tool,
(j) a first cam on said drive shaft engaging the other arm of said rocker to displace the knife edge of said tool into and out of non-sliding marking engagement with the flat of said workpiece,
(k) piston indexing means for periodically reducing the volume of liquid in said chamber to effect a predetermined axial displacement of said piston, whereby said workpiece is displaced vertically comprising:
(1) a casing defining a well in communication with said chamber and having a bore extending therethrough into said well,
(2) a plunger slidable in sealing engagement in said bore from a retracted position withdrawn

from said bore to an inserted position extending through said bore and into said well,

(3) a post extending longitudinally from that end of said plunger insertable into said well,

(4) an elongated collar coaxial with and equal in cross section to said plunger and slidable on said post a limited distance less than the length of said bore,

(5) said plunger being biased toward said retracted position, and

(6) a second cam on said drive shaft engaging said plunger to displace it between said retracted and inserted positions, and

(*l*) single driving means for imparting rotation to said drive shaft.

9. For use in precision apparatus for making diffraction gratings wherein the workpiece is supported on a piston extending from a vertical cylinder in which is defined a chamber for containing a hydraulic liquid, piston indexing means comprising:

(*a*) a casing defining a well in communication with said chamber and having a bore extending therethrough into said well,

(*b*) a plunger slidable in sealing engagement in said bore from a retracted position withdrawn from said bore to an inserted position extending through said bore and into said well,

(*c*) a post extending longitudinally from that end of said plunger insertable into said well,

(*d*) an elongated collar coaxial with and equal in cross section to said plunger and slidable on said post a limited distance less than the length of said bore,

(*e*) said plunger being biased toward said retracted position, and

(*f*) a rotatable eccentric cam engaging said plunger to displace it between said retracted and inserted positions.

10. For use in precision apparatus for making diffraction gratings wherein the workpiece is supported on a piston extending from a vertical cylinder in which is defined a chamber for containing a hydraulic liquid, piston indexing means comprising:

(*a*) a casing defining a primary well in communication with said chamber and a sump well,

(*b*) said casing also defining a first bore extending completely therethrough and through said wells and a second bore extending into only said sump well,

(*c*) a metering device slidable in sealing engagement in said first bore comprising:

(1) a plunger projecting from said casing with one end movable between a retracted position in said sump well and inserted position in said primary well,

(2) a post extending longitudinally from said plunger through said first bore and out of said casing opposite from said projecting plunger,

(3) a compression spring biasing said post into said casing,

(4) an elongated collar coaxial with and equal in cross section to said plunger and slidable on said post, and

(5) an adjustable stop on said post for limiting the sliding displacement of said collar to a distance less than the length of that portion of said first bore between said wells,

(*d*) a primer slidable in sealing engagement in said second bore into said sump well, and

(*e*) a pair of eccentric cams engaging said plunger and primer respectively to move them substantially alternately inwardly and outwardly relative to said casing.

11. In the manufacture of diffraction gratings, a method of marking a multiplicity of fine closely spaced parallel lines on an optically flat workpiece which comprises the following steps:

(*a*) normally limiting movement of said workpiece in a downward direction by pressurization of a contained body of liquid,

(*b*) moving a straight knife edge toward the flat of said workpiece in a direction perpendicular both to said edge and to the direction in which movement of said workpiece is limited,

(*c*) making simultaneous line contact between said flat and all points along said straight knife edge without sliding said knife edge relative to said flat, thereby marking a line of said flat,

(*d*) withdrawing all points along said knife edge simultaneously from said flat without sliding said knife edge relative to said flat,

(*e*) changing the volume of said body of liquid a predetermined amount so that said workpiece is indexed in that downward direction in which movement thereof is otherwise limited, and

(*f*) repeating the foregoing sequence of steps.

12. In the manufacture of diffraction gratings, a method of marking a multiplicity of fine closely spaced parallel lines on an optically flat workpiece which comprises the following steps:

(*a*) continuously urging said workpiece in a downward direction,

(*b*) limiting downward movement of said workpiece by pressurization of a contained body of liquid,

(*c*) moving a straight knife edge toward the flat of said workpiece in a direction perpendicular both to said edge and to the direction in which said workpiece is urged,

(*d*) making simultaneous line contact between said flat and all points along said straight knife edge without sliding said knife edge relative to said flat, thereby marking a line of said flat,

(*e*) withdrawing all points along said knife edge simultaneously from said flat without sliding said knife edge relative to said flat,

(*f*) reducing the volume of said body of liquid a predetermined amount so that said workpiece is indexed in the downward direction in which it is continuously urged, and

(*g*) repeating the foregoing sequence of steps.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,108,379 October 29, 1963

Arthur Harry Aaron

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 54, for "closed" read -- closer --; column 8, line 16, for "(b)" read -- (h) --; column 10, line 46, for "temperature-controlled" read -- temperature-controlling --.

Signed and sealed this 21st day of April 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents