United States Patent

Douglas

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[54] APPARATUS FOR AND METHOD OF MANUFACTURING DIFFRACTION GRATINGS

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[52] **U.S. Cl.** .....**33/19 A**
[51] **Int. Cl.**.....**B43l 13/24**
[58] **Field of Search** 33/18, 19, 32

[56] **References Cited**

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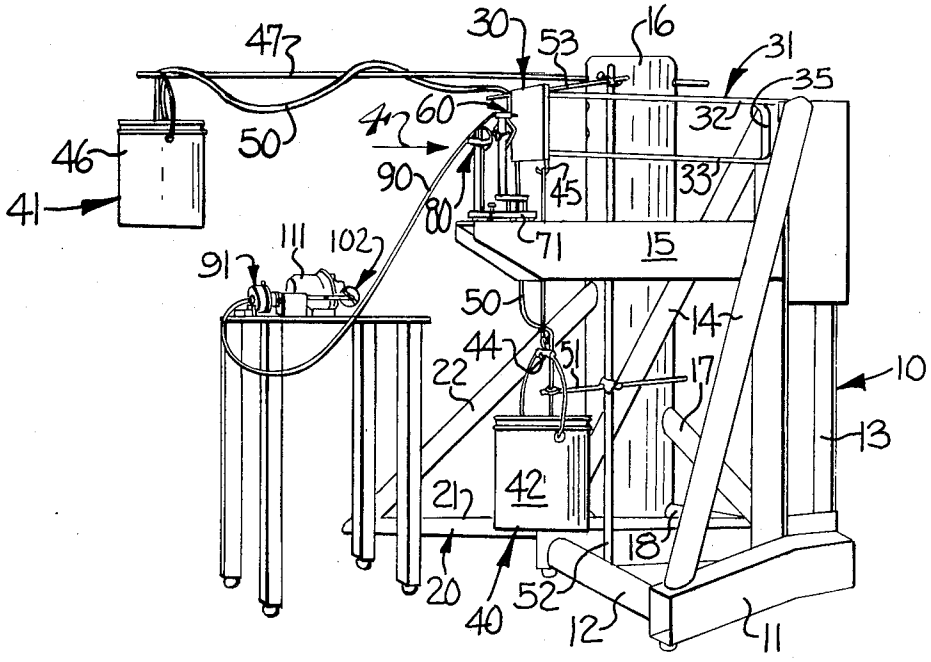
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Primary Examiner—Harry N. Haroian
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[57] **ABSTRACT**

Apparatus for and method of manufacturing diffraction gratings wherein a series of parallel lines is impressed into a workpiece which is moved at a constant rate past a line-scribing means which is cyclically moved into contact with the workpiece in a predetermined time sequence correlated to the rate of movement of the workpiece and the desired number of lines per inch, and wherein both the workpiece and scribing means are mounted by flexible, resilient members for movement by flexure of the members.

9 Claims, 8 Drawing Figures



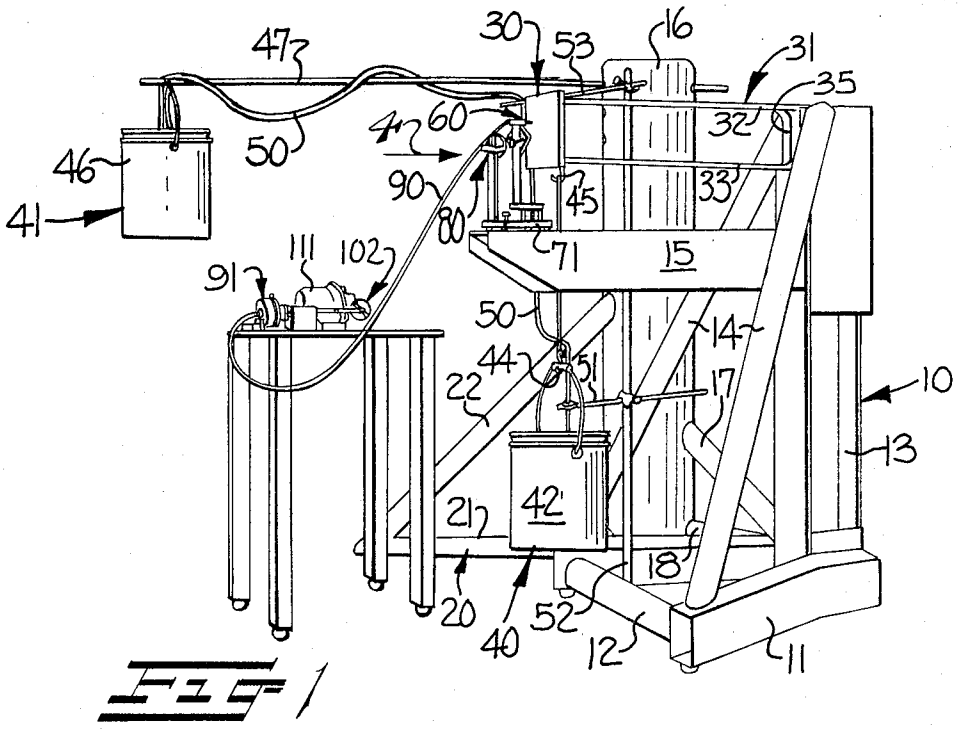


FIG. 1

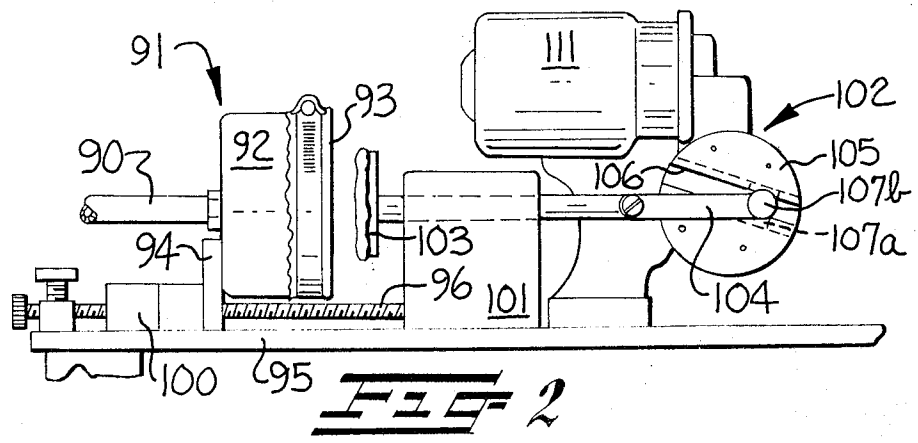


FIG. 2

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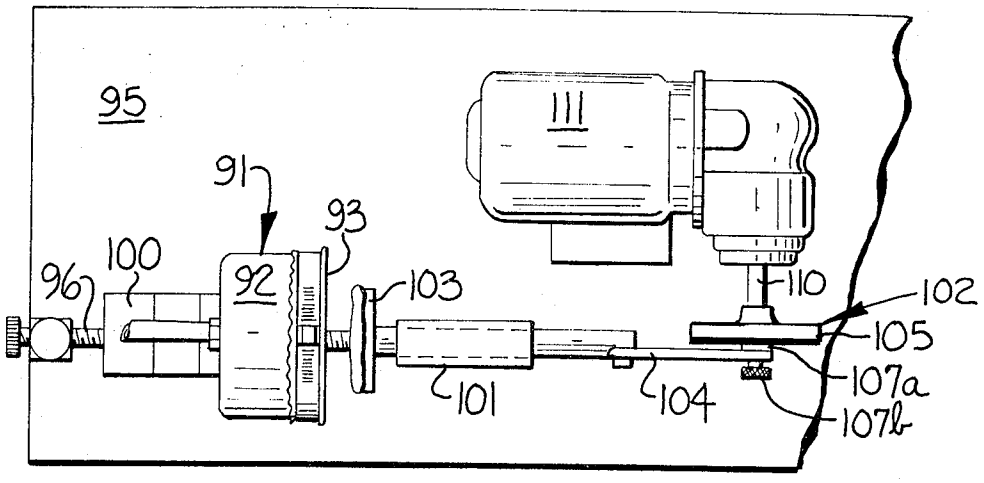


Fig. 3

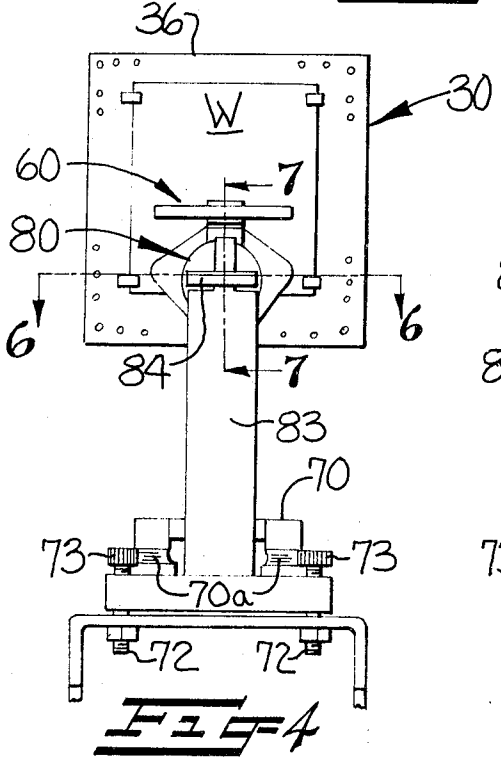


Fig. 4

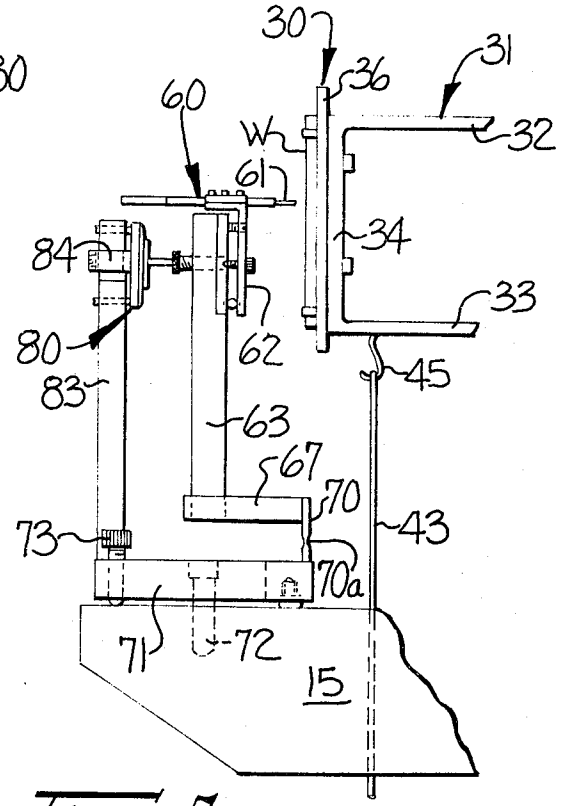


Fig. 5

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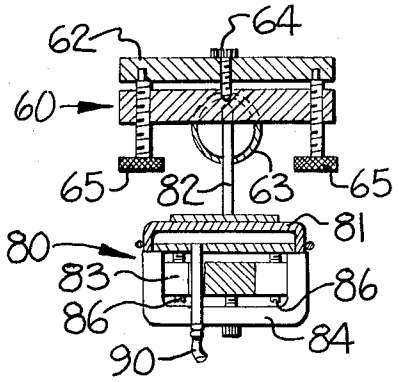


Fig-6

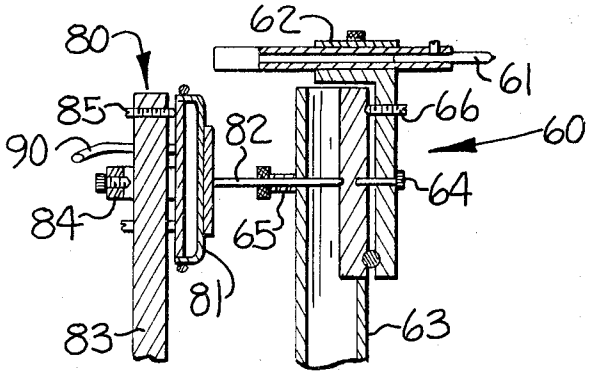


Fig-7

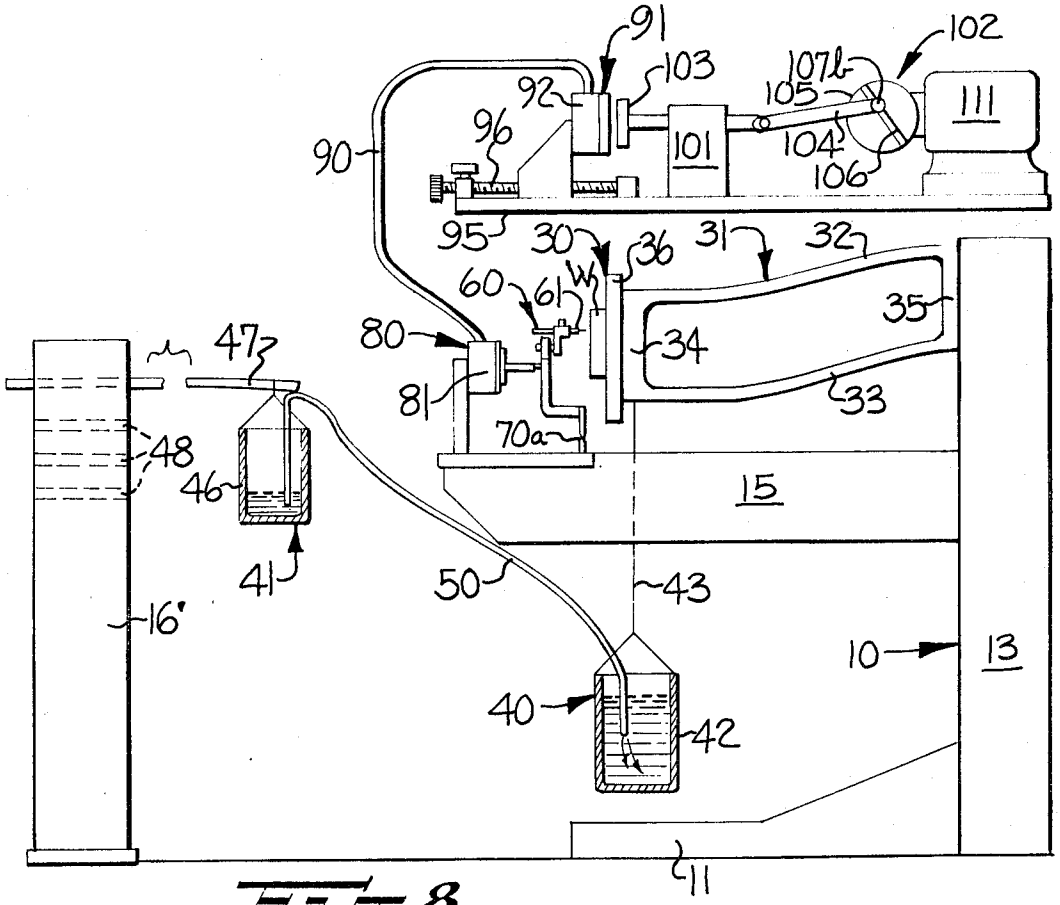


Fig-8

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APPARATUS FOR AND METHOD OF MANUFACTURING DIFFRACTION GRATINGS

This invention relates to the manufacture of diffraction gratings or other series of closely and uniformly spaced marks, made as integral parts of the surfaces of solid materials and more particularly with a novel method and apparatus used to form diffraction gratings or series of reference marks.

Diffraction gratings consist of a series of closely and uniformly spaced parallel lines formed on the surface of either a plain reflecting surface or plain transparent surface. The lines are formed at densities of from a few hundreds to the inch to many thousands to the inch and are desirably characterized by extreme uniformity of spacing and of line configuration. Diffraction gratings have widespread use in optical instruments and, in the vast majority of cases, what is used in such optical instruments is not the diffraction grating itself but a replica of that grating. Heretofore, such diffraction gratings have been formed on relatively uniform workpieces, usually in the shape of discs.

A relatively new use for diffraction gratings is that of strain gages which are used to study the deformation undergone by a solid object (a test specimen, or part of a machine, or structure under study), when that object is subjected to forces, changing temperatures or other changes in environment that cause the object to change shape. This use is by scientists and engineers studying the behavior of materials and is possible as a consequence of the change in line density of a diffraction grating in accordance with the change in dimension of the surface to which it belongs. The change in line density results in a change in the diffraction characteristics of the grating and is relateable to the change in surface dimension. Whereas in normal use in optical instruments diffraction grating replicas are used, in strain gages, it is most desirable that diffraction gratings be made integral parts of the surface of the specimen to be studied. Further, it is highly desirable to manufacture several diffraction strain gages at specific locations and orientations and on a plurality of specimens for a single experiment. Further, the workpieces involved in such diffraction strain gages are not relatively uniform, as has been the case with diffraction gratings for use in optical instruments, but are of a variety of materials and of considerably varying dimensions, configurations, and weights.

In an attempt to obtain the great regularity and uniformity of spacing, much attention has been directed to the relative indexing of the line forming tool, line-scribing or indenting means and the workpiece or specimen on which a diffraction grating is to be formed. Complex coupling systems have been devised to provide this relative indexing and have included direct and positive mechanical coupling, as by the intermittent motion of a fine lead screw; displacement as by the positive intermittent displacement of a volume of fluid; and by mechanical-electrical-optical systems. All of the indexing means heretofore employed suffer from one or more of the following disadvantages; wear and misalignment due to relative sliding movement between adjacent parts; inability to accommodate specimens of a variety of sizes, weights, and configurations; and great complexity and fragility of construction.

Accordingly, it is an object of the present invention to provide novel apparatus and method for the manufacture of diffraction gratings which obviate the aforementioned problems and disadvantages heretofore encountered with such apparatus and methods.

A more specific object of the present invention is to provide apparatus and method for the manufacture of diffraction gratings in which the relative indexing movement between the workpieces and line scribing or indenting means is continuous and at a constant velocity and the line scribing indenting means is brought into contact with the workpiece at intervals correlated to the desired number of lines per inch and the constant rate of relative indexing between the workpiece and the indenting means.

A more specific object of the present invention is to provide an apparatus for manufacturing diffraction gratings which is characterized by freedom from wear and misalignment, a capacity to accommodate workpieces of a variety of sizes, weights and configurations; and simplicity and ruggedness of construction.

Another object of the present invention is to provide apparatus for and method of producing diffraction gratings wherein the workpiece and the line scribing or indenting means are supported for movement by flexure of flexible, resilient supporting members to avoid any sliding movement where wear and misalignment may occur.

Some of the objects of the invention having been stated, other objects will appear as the description proceeds, when taken in connection with the accompanying drawings, in which

FIG. 1 is an elevational view in perspective of the apparatus of the present invention;

FIG. 2 is an enlarged fragmentary side elevational view of actuation means for an indenting tool as shown in the left medial portion of FIG. 1;

FIG. 3 is a top plan view of the actuation means shown in FIG. 2;

FIG. 4 is an enlarged, fragmentary front elevation of indenting means and workpiece mounting means looking in the direction of the arrow 4 in FIG. 1;

FIG. 5 is a fragmentary side elevation of the structure shown in FIG. 4;

FIG. 6 is a sectional view taken substantially along line 6—6 in FIG. 4;

FIG. 7 is an enlarged fragmentary sectional view taken substantially along line 7—7 in FIG. 4; and

FIG. 8 is a somewhat schematic, side elevation illustrating the use of the apparatus of the present invention.

Referring now to the drawings, especially to FIGS. 1 and 8, the apparatus of the present invention includes a support frame 10 which is made up of base members 11 and a connecting member 12. Base members 11 are suitably secured to a vertical column 13 and extend outwardly therefrom in a bifurcated manner. Connecting member 12 is positioned between the outwardly extending ends of base members 11 and is suitably secured thereto. Vertical column 13 extends upwardly and is further secured to base members 11 by diagonal supports 14 which are suitably secured at one end to the upper end of vertical column 13 and at the other ends to the ends of base members 11 adjacent connecting member 12.

A rigid support arm 15 is suitably secured at one end thereof to vertical column 13 and extends outwardly therefrom in cantilevered form. Support arm 15 is preferably of channel material and is sufficiently massive to support considerable weight and to withstand considerably shock with an absolute minimum of vibration and motion, The remainder of support frame 10 should be similarly formed of heavy and rigid members for the same reasons.

Support frame 10 also includes a second vertical support column 16 which is secured to vertical column 13 and base members 11 by a diagonal member 17 and horizontal members 18 respectively. Also, a base support frame 20, including a base member 21 and a diagonal member 22, is secured to support column 16. A sufficient number of these base support frames 20 or some other suitable support may be provided so that column 16 may be free standing and entirely separate from column 13 and base members 11 (as illustrated schematically at 16' in FIG. 8).

Workpiece mounting means 30 is provided for mounting a workpiece W in which a diffraction grating is to be formed and preferably this mounting is for constant, vertical movement at a uniform velocity. Workpiece mounting means 30 comprises a flexible, resilient member 31 mounted at one end on vertical column 13 and extending outwardly therefrom in cantilevered fashion. Member 31 comprises a pair of vertically spaced, flexible, resilient members 32, 33 rigidly interconnected at their opposite ends by connecting members 34, 35 (FIGS. 1 and 8). Member 31 may be fabricated from separate elements, but is illustrated as being formed from a single, integral member.

A workpiece support 36 (FIGS. 4 and 5) is carried by the outer end of member 31 and is adapted to receive and support the workpiece W thereon. Workpiece support 36 is constructed to receive workpieces of a variety of sizes, weights, and configurations. It is noted that the member 31 mounts workpiece support 36 for vertical movement and that the vertically spaced, flexible members 32, 33 will maintain the support in a vertical attitude during such movement, as is illustrated in FIG. 8.

Means for imparting constant motion at a predetermined rate to workpiece support 36 is provided and preferably comprises a weighting system, including a weighting means 40 connected to the workpiece support 36 and means 41 connected to the weighting means 40 for increasing the weight of the weighting means 40 at a rate required to produce downward movement of the workpiece support 36 at a constant velocity. As illustrated, the weighting means 40 comprises a container 42 having straight sides and a supporting cable 43 connected at one end to container 42 by a hook 44 and at its other end to the outer end portion of resilient member 31 by a hook 45.

Means 41 for changing the weight of weighting means 40 includes a second container 46 also having straight sides and resilient support arm 47 which is supported at one end by column 16 and supports container 46 at its other end. It is noted that resilient arm 47 is mounted in column 16 by penetrating through one of a series of vertically spaced openings 48 which permits the elevation of container 46 to be adjusted relative to the elevation of container 42 and the effective length of arm 47 to be adjusted relative to container 46.

Container 46 is connected to container 42 by a flexible siphon tube or hose 50 which has one end disposed within container 46 and the other end supported above container 42 by a bracket member 51 supported by a vertical standard 52. Vertical standard 52 has a second bracket 53 carried by the upper end thereof to support hose 50 intermediate its ends.

Container 46 is adapted to receive a predetermined amount of liquid therein at the start of the diffraction grating forming operation. The difference in elevation between containers 46 and 42 creates a predetermined head which will enable the liquid to be siphoned from container 46 into container 42 to gradually increase the weight of container 42 and thereby to downwardly flex resilient member 31 to move workpiece support 36 downwardly.

A particular feature of the present invention is to maintain a very constant flow rate of liquid between the container 46 and container 42. This is accomplished by maintaining a constant head, which is the vertical distance between the surface of the liquid in container 46 and the lower end of siphon hose 50 if the lower end of siphon hose 50 is above the liquid in container 42 or between the surfaces of the liquid in the two containers 42 and 46 if the lower end of the siphon hose is below the surface of the liquid in container 42. A constant head is maintained by suspending container 46 by resilient arm 47, the effective length of which is adjustable and hence the effective resilience of which is adjustable. Thus, as liquid is siphoned from container 46, the level of the liquid therein lowers but, at the same time, the weight at the end of resilient member 47 is decreased, If the length of resilient member 47 is properly selected, the container 46 will rise as the liquid level therein lowers and this upward movement will be at the same rate as the change in head which would otherwise occur.

Line scribing or indenting means, indicated generally at 60 (FIGS. 4, 5, 6 and 7) is provided for marking lines upon a workpiece W supported by support 36 and is mounted for cyclic movement toward and away from support 36 in timed relation to the movement of workpiece support 36 correlated to the velocity of such movement and the desired number of lines per inch in the workpiece W. The indenting means 60 includes an indenting tool 61 and the means for mounting indenting means 60 includes a mounting head 62 adjustably mounting tool 61 therein. In order to mark a line upon the workpiece W with each contact of the indenting tool 61 thereagainst, the indenting tool includes an elongate straight knife edge, the length of which determines the length of the lines scribed into the workpiece. Mounting head 62 is in turn adjustably mounted on the upper end of a column 63 by a mounting screw 64 and positioning screws 65 and 66.

Column 63 is mounted at its lower end on a horizontal support member 67 which in turn is mounted on a flexible hinge member 70. Member 70 has a reduced thickness hinge portion 70*a* intermediate its ends to increase its ability to flex.

Member 70 is mounted on a baseplate 71 removably and adjustably secured to rigid support arm 15 by bolts 72. Baseplate 71 is capable of horizontal adjustment toward and away from column 13 and hence workpiece support 36 to properly position indenting means 60 relative to the workpiece by positioning hinge member 70 directly beneath workpiece W. This positioning is permitted by the column 63 being offset from hinge member 70 by horizontal member 67. Baseplate 71 also has leveling screws 73 threadably mounted therein for engagement with the upper surface of rigid support arm 15 to level base plate 71 relative to the horizontal.

Means is provided for imparting cyclic motion to the indenting means 60 and comprises a pressure impulse responsive means 80 including a flexible pressure responsive diaphragm 81 defining a chamber therein which normally is of predetermined volume but which increases in volume upon expansion of diaphragm 81. Diaphragm 81 is connected to column 63 by a connecting rod 82 for moving the column 63 about pivot 70*a* upon increases in pressure within the pressure impulse responsive means 80. Pressure responsive means 80 is mounted on a standard 83 which in turn is mounted on baseplate 71. The mounting means for pressure impulse responsive means 80 includes a bracket 84 surrounding the standard 83 and a set screw 85 threadably mounted therein for engagement with the standard 83 so that pressure impulse responsive means 80 is mounted for vertical adjustment on standard 83. Positioning screws 86 are also provided for varying the alignment of the diaphragm 81 with the column 63.

Pressure impulse responsive means 80 is connected by a conduit 90 to a source of pressure impulses 91 which cause sequential expansion and contraction of the diaphragm 81 to cyclically move the indenting means 60. The pressure impulse means 91 includes a housing 92 and a flexible diaphragm 93 covering one end of housing 92 and defining therein a confined space or chamber having fluid therein. It is noted that the pressure impulse responsive means 80, conduit 90 and impulse generating means 91 define a closed fluid system so that contraction of the enclosed space within housing 92 results in extension of the diaphragm 81 and expansion of the chamber within pressure impulse responsive means 80, and subsequently expansion of the enclosed space within housing 92 back to its original size results in contraction of diaphragm 81 and a return to its original position.

Housing 92 is mounted on a bracket 94 which is adjustably mounted on a suitable support 95, such as a table, by being threadably mounted on a lead screw 96. Lead screw 96 is rotatably mounted on support 95 by spaced-apart brackets 100 and 101.

Means 102 is provided for cyclically contracting the enclosed space within housing 92 and includes a ram 103 slidably mounted for reciprocatory movement in bracket 101 and being positioned in alignment with the flexible diaphragm 93 on housing 92. Ram 103 is pivotally connected to a crank arm 104 which in turn is pivotally connected to an eccentric 105. It is noted that the connection between crank 104 and eccentric 105 is adjustable by means of a slot 106 being provided in eccentric 105 and a connection 107 between the crank 104 and the eccentric 105 comprising a slide member 107*a* disposed in slot 106 and a thread screw 17*b* penetrating through the crank 104 and being threadably mounted in the slide 107*a*. Eccentric 105 is suitably mounted on an output shaft 110 of a suitable synchronous gear motor 111 which drives the eccentric 105 at a constant speed.

In operation, a suitable workpiece W is mounted on workpiece support **36** and a predetermined amount of liquid is placed in container **46**. At the start of this operation the resilient member **31** is substantially unflexed and the indenting tool **61** is at the bottom of the portion of the workpiece W in which the diffraction grating is to be formed.

The indenting means **60** and the mounting means therefor are adjusted along support arm **15** until the hinge **70***a* is positioned directly beneath the workpiece W. The impulse generating means **91** is adjusted along lead screw **96** to position the diaphragm **93** relative to the ram **103** to set the magnitude of the pressure impulses to be generated by contraction of the space within housing **92** by contact of the ram with diaphragm **93**.

Substantially simultaneously, gear motor **111** is actuated to drive eccentric **105** and hence ram **103** to generate pressure impulses to cyclically move indenting means **60** toward and away from the workpiece W and the siphoning means is activated to provide a constant flow of liquid from container **46** to container **42**. This transfer of liquid effects a constant downward movement of the workpiece W relative to the indenting means **60**. The cyclic movement of the indenting means **60** and downward movement of the workpiece W is correlated to provide the desired number of lines per inch in the workpiece W to form the diffraction grating.

It will, therefore, be apparent that a novel apparatus and method of forming diffraction gratings is provided wherein continuous relative indexing movement between the workpiece and indenting means at a constant velocity and cyclic movement of an indenting means provides highly accurate and uniform line formation, and which will accommodate workpieces of a variety of sizes, weights and configurations and which can form diffraction gratings in subsequent workpieces with a very high degree of uniformity of lines and spacing.

In the drawings and specification there has been set forth a preferred embodiment of the invention, and although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation:

What is claimed is:

1. Apparatus for producing diffraction gratings wherein a multiplicity of fine, closely spaced, parallel lines are scribed on a planar surface of a workpiece comprising

elongated scribing means for marking lines upon the planar surface of a workpiece,

workpiece mounting means for mounting the workpiece with its planar surface disposed perpendicular to said elongated scribing means,

first mounting means for mounting said elongated scribing means for movement toward and away from said workpiece mounting means, said first mounting means including a mounting member having a flexible, resilient hinge portion and an offset portion spaced therefrom for movement about the hinge portion through flexure thereof,

second mounting means mounting said workpiece mounting means for movement in the same plane as the flexible, resilient hinge portion of said mounting member and in the same plane as said planar surface of said workpiece,

said mounting means cooperating in maintaining said elongated scribing means and said workpiece in a particular attitude one relative to the other to maintain said elongated scribing means perpendicular to the planar surface of the workpiece,

first moving means connected to said first mounting means for imparting cyclic motion in a predetermined time sequence to said one of said scribing and workpiece mounting means mounted for movement in said first direction, and

second moving means connected to said one of said scribing and workpiece mounting means mounted for movement in said second direction for imparting constant motion thereto in said second direction at a rate correlated to the time sequence of cyclic movement in said first direction and to the desired number of lines per inch.

2. Apparatus for producing diffraction gratings wherein a multiplicity of fine, closely spaced, parallel lines are marked on a planar surface of a workpiece comprising:

elongated scribing means for marking lines upon the planar surface of a workpiece,

workpiece-mounting means for mounting workpiece with its planar surface disposed perpendicular to said elongated scribing means,

means mounting said elongated scribing means for movement toward and away from the workpiece-mounting means,

a pair of spaced, generally parallel flexible resilient arm members rigidly interconnected at their opposite ends and supporting said workpiece-mounting means at one end thereof, said pair of arm members being rigidly supported at their other end for movement of said workpiece mounting means substantially in a single plane due to flexure of said arm means,

first moving means connected to the said scribing means mounting means for imparting cyclic motion in a predetermined time sequence to said elongated scribing means, and

second moving means connected to said pair of resilient arm members whereby imparting constant motion thereto in a direction perpendicular to the movement of said scribing means at a rate correlated to the time sequence of cyclic movement of said scribing means and to the desired number of lines per inch.

3. Apparatus according to claim **2** wherein said second moving means is connected to said second mounting means and comprises

a fluid container suspended below the workpiece mounting means carried by said second mounting means,

a second fluid container disposed at a higher elevation than said first fluid container,

siphoning means connecting said second container to said first container for siphoning liquid from the second container into the first container at a constant flow rate, and

means mounting said second container for vertical movement at a rate correlated to the rate of withdrawal of liquid therefrom and hence the rate of downward movement of said first container.

4. A method of producing diffraction gratings wherein a multiplicity of fine, closely spaced, parallel lines are marked on a planar surface of a workpiece comprising the steps of

mounting an elongated scribing tool and a workpiece having a planar surface for relative movement therebetween in generally perpendicular first and second directions, then

imparting cyclical motion in a predetermined time sequence in the first direction and displacing one of the scribing tool and the workpiece toward and away from the other to indent lines into the planar workpiece surface with the scribing tool while

applying a constantly increasing weight to a resiliently displaceable workpiece support while maintaining the rates of weight increase and resilient deflection constant and thereby imparting constant motion in the second direction at a rate correlated to the time sequence of cyclic movement in the first direction and to a desired number of lines per inch and displacing the workpiece in a plane parallel to the planar workpiece surface to displace indented lines in the workpiece into parallel spaced relation.

5. A method according to claim **4** wherein the imparting of cyclical motion includes generating cyclical fluid pressure pulses and the displacing of one of the indenting tool and workpiece includes applying the generated pulses to the indenting tool to move the same toward the workpiece.

6. A method according to claim **4** wherein the applying of increasing weight includes transferring weighting liquid into container connected to the resiliently displaceable workpiece support and the maintaining of a constant rate of weight increase includes maintaining a constant flow rate of liquid into the container.

7. A method according to claim 4 wherein the applying of increasing weight includes siphoning weight liquid from a supply container into a weighting container connected to the resiliently displaceable workpiece support and the maintaining of a constant rate of weight increase includes maintaining a constant head during the siphoning.

8. A method according to claim 7 wherein the maintaining a constant head during siphoning includes moving the supply and weighting container vertically one relative to the other at a rate correlated to the transfer of liquid therebetween.

9. A method of producing diffraction gratings wherein a multiplicity of fine, closely spaced, parallel lines are marked on a planar surface of a workpiece comprising the steps of

mounting an elongated scribing tool and a workpiece having a planar surface for relative movement therebetween in generally perpendicular first and second directions, then

imparting cyclical motion in a predetermined time sequence in the first direction and pivoting the elongated scribing tool toward and away from the workpiece about a pivot location lying in the plane of the planar workpiece surface to thereby indent lines into the planar workpiece surface with the elongated scribing tool while

imparting constant motion in the second direction at a rate correlated to the time sequence of cyclic movement in the first direction and to a desired number of lines per inch and displacing the workpiece in a plane parallel to the planar workpiece surface to displace indented lines in the workpiece into parallel spaced relation.

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