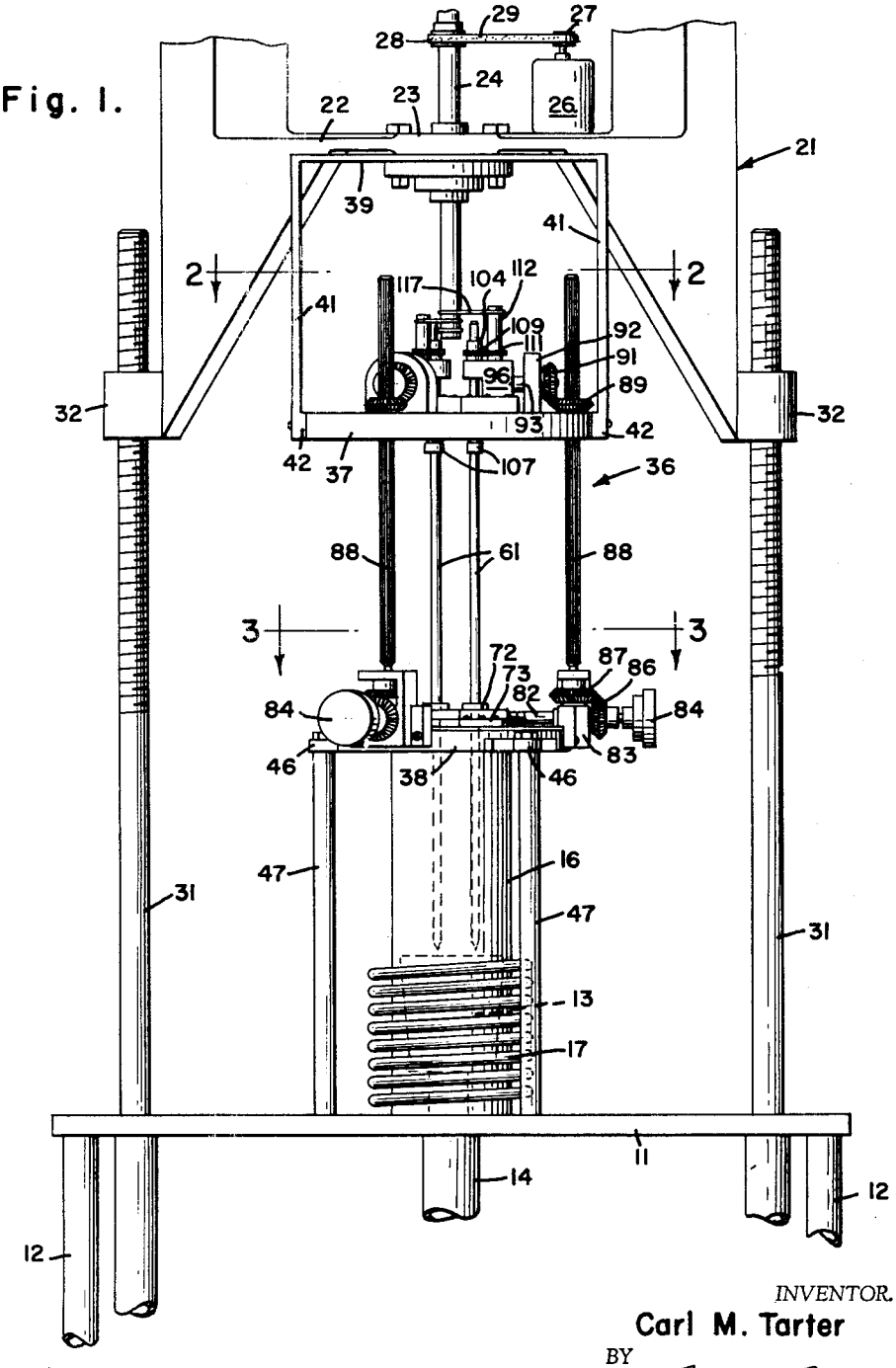
Aug. 11, 1964 C. M. TARTER 3,144,308

MULTIPLE CRYSTAL GROWING HEAD

Filed July 3, 1961 3 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

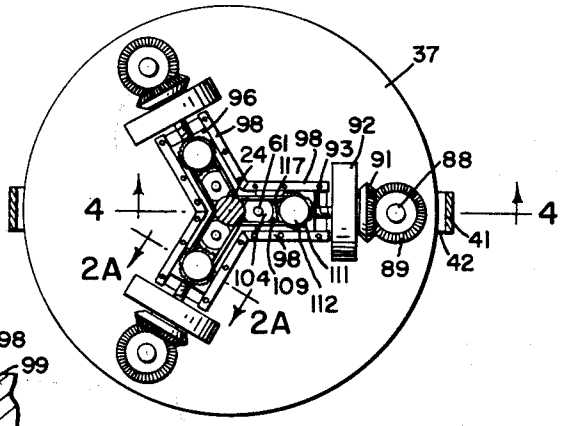
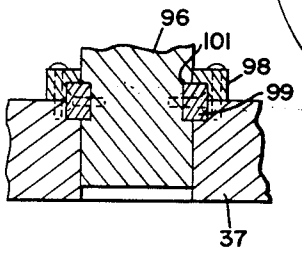


Fig. 2A.



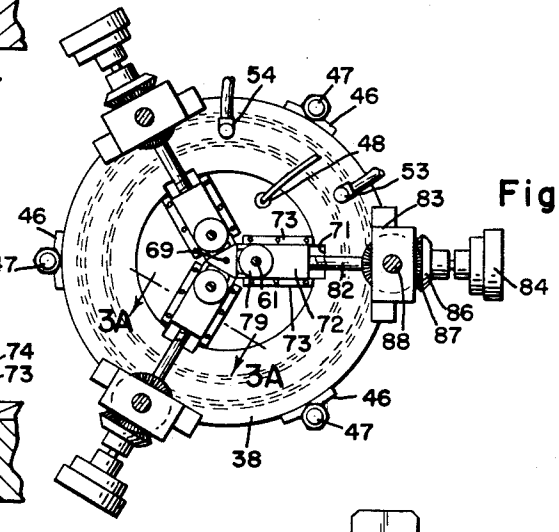


Fig. 3.

Fig. 3A.

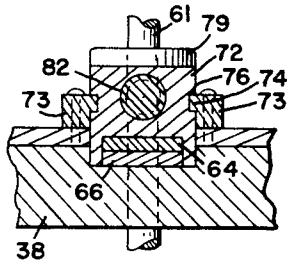
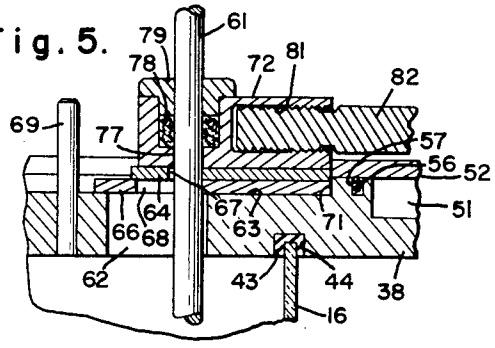


Fig. 5.



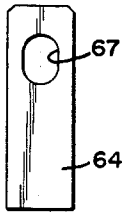


Fig. 6.

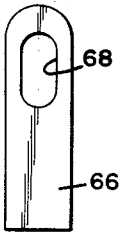


Fig. 7.

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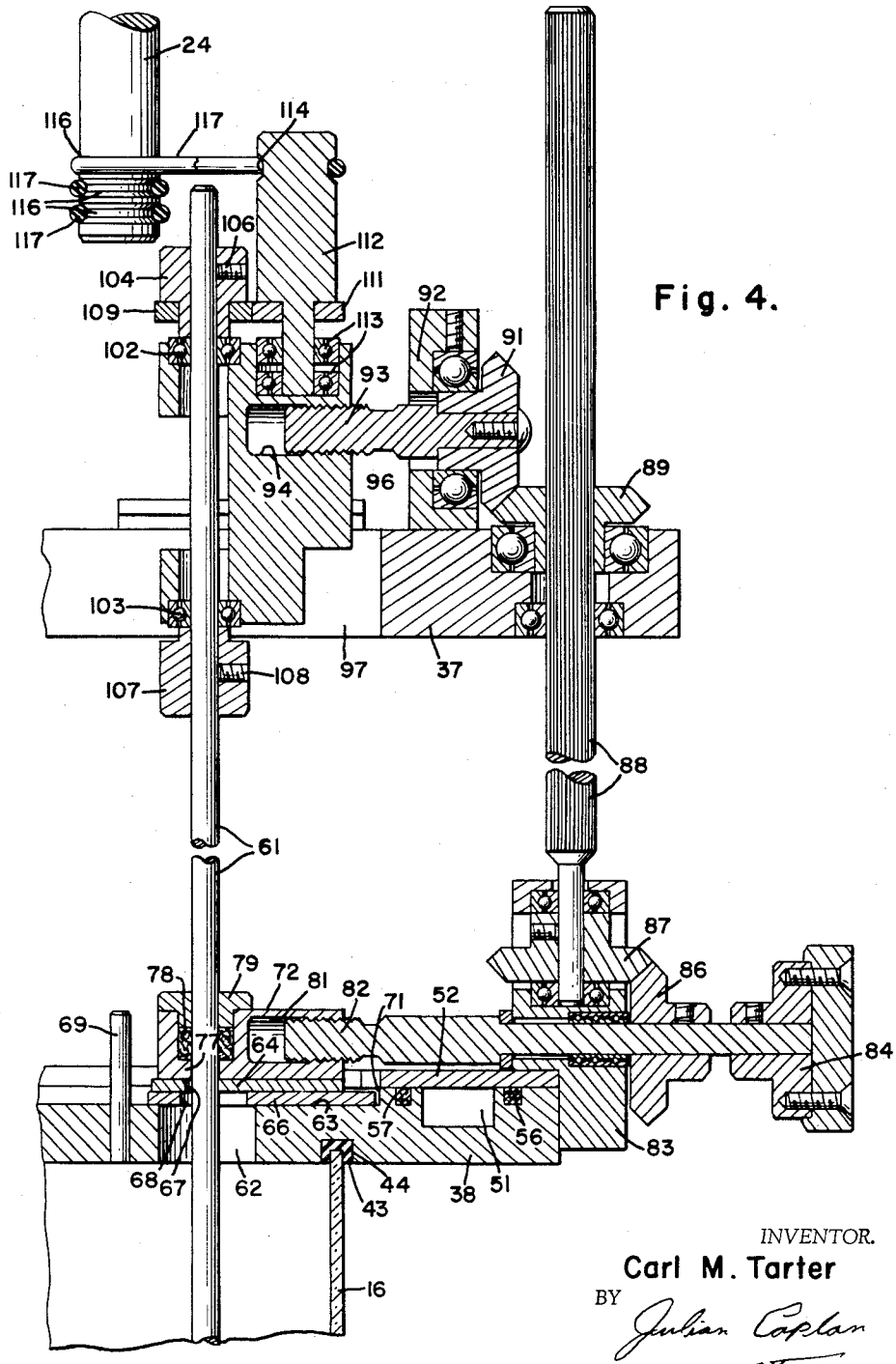


Fig. 4.

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3,144,308

MULTIPLE CRYSTAL GROWING HEAD

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Filed July 3, 1961, Ser. No. 123,354
8 Claims. (Cl. 23—273)

This invention relates to a new and useful improvement in multiple crystal growing head. More particularly the present invention relates to a modification of existing crystal growing equipment of the type for silicon crystals and the like. In such conventional machines there is provided a crucible which is heated to a temperature sufficient to melt the silicon or other material being crystallized and which is sealed from the atmosphere and blanketed with an inert gas such as helium. A seed rod is inserted in the crucible and rotated and causes the formation of a crystal at the base of the rod. As the crystal grows the rod is raised and thereby the crystal is elongated.

The present invention comprises an improvement on such equipment which makes it possible to grow a plurality of crystals at one time from a single crucible.

A particular feature and advantage of the present invention is the fact that the temperature at the base of each of the seed rods may be adjusted individually. Such adjustment is accomplished by moving the rod in a radial direction with respect to the crucible, it being understood that the crucible is hottest at its exterior where the heating coils are located.

A further feature and advantage of the present invention is the fact that means is provided to seal the head to the crucible, which seal is maintained regardless of the position of adjustment of each of the rods and which further permits the radial adjustment of the rods through a wide range.

Another advantage of the invention is the fact that each rod may be adjusted to a position very close to the center of the crucible, thus further facilitating a wide variation in temperature of the various seed rods.

Still another feature of the invention is the fact that each of the rods is maintained in vertical alignment independently of the others and is supported top and bottom, the top and bottom supports moving inwardly and outwardly equidistantly for each individual rod.

Still a further feature of the invention is the provision of means for individually adjusting the speed of each rod if required.

Other objects of the present invention will become apparent upon reading the following specification and referring to the accompanying drawings in which similar characters of reference represent corresponding parts in each of the several views.

In the drawings:

FIG. 1 is a side elevation of a portion of a crystal growing machine with the present invention incorporated therein.

FIGS. 2 and 3 are transverse horizontal sectional views taken substantially along the lines 2—2 and 3—3, respectively, of FIG. 1.

FIGS. 2*a* and 3*a* are fragmentary sectional views taken along corresponding lines in FIGS. 2 and 3, respectively.

FIG. 4 is a fragmentary enlarged vertical sectional view taken substantially along the line 4—4 of FIG. 2.

FIG. 5 is a fragmentary enlarged sectional view through the gas slide mechanism showing such mechanism in a different position of adjustment from that shown in FIG. 4.

FIGS. 6 and 7 are plan views of the top and bottom gas slides respectively.

Crystal growing equipment is well understood in this

art and only portions of a machine for such purpose are illustrated herein. A base plate 11 is provided horizontally disposed and supported by legs 12. Mounted on base plate 11 is a crucible 13 which is in turn rotated by means of crucible rotating shaft 14 vertically disposed and driven by means forming no part of the present invention and not herein illustrated in detail. Surrounding crucible 13 is a casing 16 and around casing 16 are heating elements 17 which heat crucible 13 to a temperature sufficient to melt the material contained therein. Such material may be silicon in a preferred embodiment of the invention.

Spaced at a variable distance above base plate 11 is a superstructure 21 having a horizontal web 22 provided with a bearing 23 in which is vertically rotatable a rod driveshaft 24. Driveshaft 24 is driven by electric motor 26 through pulleys 27–28 and interconnecting belt 29. To raise and lower superstructure 21, there may be provided a plurality of vertical screws 31 mounted in base plate 11 which are driven in synchronism by means not herein illustrated, screws 31 being in threaded engagement with nuts 32 on superstructure 21 so that as screws 31 turn the superstructure is raised relative to crucible 13. The rate of elevation of superstructure 21 is related to the rate of growth of the crystals in the crucible.

The present invention is concerned primarily with the crystal growing head 36 located between superstructure 21 and casing 16. Head 36 comprises a number of elements which are supported primarily by means of top and bottom plates 37, 38, respectively. Top plate 37 depends from web 22, there being a bracket having center portion 39 fastened to web 22 and vertical legs 41, lower ends of bracket legs 41 having feet 42 connected to top plate 37. Bottom plate 38 rests upon casing 16 and is sealed thereagainst by means of gasket 43 inserted in a groove 44 in the bottom of plate 38 and sealing against the upper edge of casing 16. Side lugs 46 are attached to the perimeter of plate 38 and formed with vertical holes to receive rods 47 on base plate 11. A gas such as helium is fed into casing 16 through fitting 48 in plate 38 and is connected to a suitable source of gas. The purpose of the gas is to blanket crucible 13 and prevent oxidation of the contents and is under sufficient pressure to prevent entry of atmosphere into casing 16. Further, it is desirable that bottom plate 38 be cooled, and for such purpose passageways 51 for cooling water are provided in the top surface of plate 38. An annular cover ring 52 is positioned over the cooling water passageways 51 to form an enclosure, and suitable water inlet and outlet connections 53, 54 provided to maintain circulation of water through the cooling passageways. Gaskets 56 in circular grooves 57 seal ring 52 to plate 38.

In accordance with the present invention there are provided a plurality of seed rods 61 here shown as three in number and ¼ inch in diameter. Such seed rods 61 extend from a position slightly above top plate 37 through bottom plate 38 and into casing 16 and into crucible 13. The lower tips of rods 61 comprise the seed around which the crystals of silicon or the like grow. As the crystals grow rods 61 are raised by upward movement of superstructure 21. The present invention provides means for rotating rods 61 individually from the driveshaft 24 and at the same time moving rods 61 radially each independently of the other.

For purpose of permitting radial movement of rods 61 relative to bottom plate 38, there are provided in bottom plate 38 three radially disposed slots 62. The slots 62 are preferably of an effective length of about ½ inch and permit each rod 61 to move from adjacent the central axis of crucible 13 outwardly a distance of ½ inch. Such

radial movement permits considerable adjustment in the temperature at the base of the rod.

To prevent escape of gas through the portion of slots **62** not occupied by rods **61**, the top surface of bottom plate **38** is formed with radially extending grooves **63** in alignment with slots **62**, and within grooves **63** are top and bottom horizontally slidable gas slides **64**, **66** formed of a material such as 50% glass Teflon. Top slide **64** is formed with a hole **67** which is of the width of seed rod **61** and is slightly elongated to an effective length about .100 inch greater than the diameter of said rod **61**. Bottom slide **66** is longer than top slide **64** and is formed with an elongated slot **68** having an effective length about .312 inch greater than the diameter of seed rod **61**. The lengths of the slides **64**, **66** and of the slots **67**, **68** therein are such that when rod **61** is moved radially by means hereinafter explained, the slides at all times conceal slot **62** except for the passageway of rod **61** therethrough. To facilitate sliding movement of slides **64**, **66** there is a vertical pin **69** located in center of plate **38** where the three grooves **63** converge. When rod **61** is at the extreme outer position of its movement as shown in FIG. 5, the outer ends of slides **64**, **66** abut the outer end **71** of groove **63**. As rod **61** is moved inwardly it pushes top slide **64** inwardly (because of the restricted length of slot **67**), the progression of such movement being shown by contrast of FIG. 5 with FIG. 4. Further inward movement beyond that shown in FIG. 4 causes rod **61** to engage the inner end of slot **68** of lower slide **66** and to move slide **66** radially inwardly until it contacts pin **69** which stops the movement. Thus, regardless of the radial position of rod **61**, slot **62** is closed off by slides **64**, **66**. Downward pressure of slides **64**, **66** is maintained by means of adjustment block **72**, or guide there being one such block **72** for each rod **61**. Adjustment block is held to permit radial movement but prevent vertical movement by gibs **73** fastened to plate **38** and having projections **74** fitting into horizontal grooves **76** in block **72**. Adjustment block **72** has a vertical bore **77** for seed rod **61** provided with seal **78** surrounding rod **61** and held in place with proper adjustment of pressure by means of cap **79**. A threaded horizontally radially outwardly facing hole **81** receives the threaded inner end of adjustment screw **82**. Adjustment screw **82** extends radially outwardly and is supported at the outer edge of plate **38** by means of bearing block **83**. Adjustment knob **84** on the outer end of screw **82** permits manual turning of screw **82** and such movement is transformed into radial movement of block **72** and of the rod **61** supported therein. Each rod **61** is individually adjustable by turning its knob **84**.

As previously stated, a feature of the present invention is the provision of means whereby the upper end of each rod **61** is moved in a radial direction a distance equal to the movement of the lower end of the rod. For such purpose for each seed rod **61** there is mounted on screw **82** a bevel gear **86** which meshes with bevel gear **87** on the lower end of a vertically disposed splined rod **88** which passes through upper plate **37**. Upper plate **37** carries a bevel gear **89** rotatably mounted thereon and turning with splined rod **88** but vertically slidable along rod **88**, and gear **89** meshes with gear **91** journalled in upper bearing block **92** on plate **37** and carrying upper lead screw **93**. Upper lead screw **93** is threaded into a bore **94** in upper block **96** or guide which moves in a radial direction in radial slot **97** in plate **37**. Gibs **98** fastened to plate **37** have projections **99** fitting into horizontal grooves **101** in block **96** and guiding block **96** for horizontal radial movement only. Bearings **102**, **103** are mounted at the top and bottom of block **96** to receive seed rod **61**. The upper bearing **102** carries a stop **104** which is attached to rod **61** by means of set screw **106** and lower bearing **103** carries a similar stop **107** likewise attached to rod **61** by set screw **108**. This insures that rod **61** moves vertically as upper plate **37** moves. Upper stop **104** also carries a pinion **109** which meshes with pinion **111** on

spindle **112** rotatably mounted by means of bearings **113** in block **96**. The upper end of spindle **112** has a groove **114** which functions as a pulley and is connected to groove **116** in lower end of drive rod **24** by means of belt **117**. Belt **117** is elastic so that as block **96** moves radially the drive between drive rod **24** and spindle **112** is maintained. It will be noted that the elevation of the grooves **114** in the three spindles **112** for the three seed rods **61** are different but that in all other respects the means for moving the seed rods radially is identical.

Operation

The essential operation of the apparatus heretofore described is in several respects the same as in conventional crystal growing apparatus. Thus the crucible **13** is provided with silicon or similar material to form the crystal. Heat is applied to the heating coil **17** which raises the material to its melting point, it being observed that the material is hottest at its perimeter where it is adjacent the heating coils and that the temperature decreases as the distance from the perimeter increases. Crucible **13** is rotated by shaft **14** by means well understood in this art and not illustrated herein. At the outset, seed rods **61** are installed in each of slots **97**, the upper end of the rod being retained to move with upper plate **37** by means of stops **104** and **107** in engagement therewith. The seed rods **61** extend through packing **78** and through the apertures **67**, **68** in upper and lower slides **64**, **66** thence through the slot **62** in lower plate **38** and through casing **16** into crucible **13**. Each rod **61** is caused to rotate by reason of rotation of drive rod **24**, belt **117**, spindle **112**, and gears **111–109**, the latter of which is rotatable with stop **104** and rod **61**. As the crystals form on the bottom of seed rod **61**, the rod is gradually raised by turning screws **31** which in turn raises superstructure **21** and upper plate **37**. Upper plate **37** slides along the splined drive rod **88**.

It is desirable that the temperature of the crystal formed at the bottom of each seed rod be maintained at the optimum and this requires inward and outward movement of the seed rod in a radial direction. This is accomplished by turning adjustment knob **84** on lower threaded rod **82**. By reason of the gear train **86**, **87** and rotation of the splined rod **88** and gear train **89–91** an equal turning movement is imparted to upper threaded rod **93**. This results in lower block **72** and upper block **96** moving radially an identical distance and hence seed rod **61** is at all times vertical regardless of its position of adjustment.

A gas such as helium is maintained inside casing **16** to prevent oxidation. Such gas is admitted to the casing through port **48**. Slides **64–66** prevent escape of the gas. Thus when the seed rod **61** is at its outer limit, lower slide **66** is retracted until its outer end abuts the outer end **71** of groove **63** in which the slide is mounted and thereafter outward movement of the lower slide ceases. In such position, as shown in FIG. 4, the inner end of lower slide **66** overlaps the inner end of slot **62** and hence the seal is maintained. Further inward movement of seed rod **61** is permitted by reason of sliding of the upper slide **64** over lower slide **66** and such movement is continued until the position of FIG. 5 is reached, which position is the outer limit of movement of the seed rod and brings the outer end of upper slide **64** into contact with the end **71** of groove **63**. The inward movement of the seed rod **61** from the extreme position of FIG. 5 first moves the upper and lower slides **64**, **66** to the position shown in FIG. 4. Further inward movement results in inward movement of the lower slide **66** until its inner end abuts central pin **69**, at which time the seed rod has reached the limit of its inward movement.

It will thus be seen that the three seed rods **61** may be moved in a radial direction, each independently of the other by adjustment of its respective adjustment knob **84** even when the rods are rotating. The limit of the move-

ment is the length of slot 62. Regardless of the position of adjustment of the seed rod, a seal is maintained by slides 64, 66. As the crystal is formed and as the upper plate is raised 37, the adjustment is maintained by reason of gear 89 on upper plate 37 sliding along splined rod 88. Regardless of the radial position of seed rod 61, the driving relationship between drive shaft 24 and the seed rod is maintained because of the fact that belt 117 stretches to permit the radial movement.

Although the foregoing invention has been described in some detail, by way of illustration and example for purposes of clarity of understanding, it is understood that certain changes and modifications may be practiced within the spirit of the invention and scope of the appended claims.

What is claimed is:

1. A crystal growing head comprising a lower plate formed with at least one radial first slot, a top plate above and vertically movable relative to said lower plate and formed with a second slot vertically aligned with said first slot, a seed rod extending through said slots and below said first plate, a first guide apertured for said seed rod, first means mounting said first guide for movement on said lower plate parallel to said first slot, a second guide apertured for said seed rod and mounting said seed rod for vertical movement with said top plate and rotative movement, second means mounting said second guide for movement on said top plate parallel to said second slot, adjustable third means for adjusting the radial position of said first guide, fourth means interconnecting said first and second means for equal radial movements of said first and second guides, and sealing means interposed between said bottom plate and said first guide sealing against escape of gas through said first slot around said seed rod.

2. A head according to claim 1 in which said fourth means is vertically extensible.

3. A head according to claim 1 in which said fourth means comprises a vertical rod interconnecting said top and bottom plates and gear trains for transmitting motion from said third means to said rod and from said rod to said second guide.

4. A head according to claim 1 in which said sealing means comprises a bottom slide and a top slide parallel to said bottom slide, said slides being interposed between said bottom plate and said first guide over said first slot, means confining said slides to radial movement and inner and outer abutments limiting radial movement of said slides to the length of said first slot, each said slide being formed with an aperture to receive said seed rod, one of said apertures being elongated in a radial direction.

5. A crystal growing head comprising a lower plate formed with a plurality of radial first slots, a top plate above said lower plate formed with a corresponding plurality of second slots vertically aligned with said first slots, means for raising and lowering said top plate relative to said lower plate, a seed rod for each said first slot extending through a first and a second slot and movable radially therein, and for each said rod a first guide vertically apertured to receive said seed rod, first means mounting said first guide for movement on said lower plate parallel to said first slot, a second guide rotatably mounting said seed rod for movement therewith, second means mounting said second guide for movement on said top plate parallel to said first slot, third means manually adjustable for moving said first guide radially on said lower plate along said first slot, fourth means for moving said second guide radially on said top plate, fifth means for moving said third and fourth means equal radial distances, said fifth means being vertically extensible to permit relative vertical movement of said top and bottom plates, and sealing means interposed between said bottom plate and said first guide sealing off said first slot around the perimeter of said seed rod to prevent escape of gas through said seed rod.

6. A head according to claim 5 in which said sealing means comprises a bottom slide and a top slide parallel to said bottom slide, said slides being interposed between said bottom plate and said first guide over said first slot, means confining said slides to radial movement and inner and outer abutments limiting radial movement of said slides to the length of said first slot, each said slide being formed with an aperture to receive said seed rod, one of said apertures being elongated in a radial direction.

7. A crystal growing head comprising a lower plate formed with a plurality of first slots each radially disposed, a top plate above and vertically movable relative to said lower plate and formed with a plurality of second slots vertically aligned with said first slots, a plurality of seed rods each extending through one of said first and one of said second slots, means mounting said rods for moving each said seed rod individually radially within said slots, and sealing means for each said seed rod sealing around said seed rod over said first slot and against said lower plate, said sealing means being operable in any position of radial movement of said seed rod.

8. A head according to claim 7 in which said sealing means comprises a guide around said seed rod mounted for movement over said lower plate, a top and bottom slide between said guide and said lower plate over said first slot, means confining said slides to radial movement and abutment means limiting radial movement of said slides, each said slide being formed with an aperture to receive said seed rod, one of said apertures being elongated in a radial direction.

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