United States Patent

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[54] APPARATUS FOR GROWING CRYSTALLINE BODIES

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[51] **Int. Cl.** **B01j 17/18**

[58] **Field of Search** ..... 23/301 SP, 273 SP, 279, 283, 23/282, 277

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[57] **ABSTRACT**

The apparatus comprises a gastight furnace locating a crucible which may be rotated by a motor located under the furnace. A rod vertically movable in a tubular extension of the furnace cover is adapted to pull a crystal from a melt in the crucible. The cover has a side arm which is pivotally connected to a lateral extension of a vertical shaft adapted to swing about its axis into a position where the crystal clears the furnace only after the shaft has been raised to a predetermined position. Additional pivotal movement of the side arm then provides access to the furnace body if necessary.

8 Claims, 4 Drawing Figures

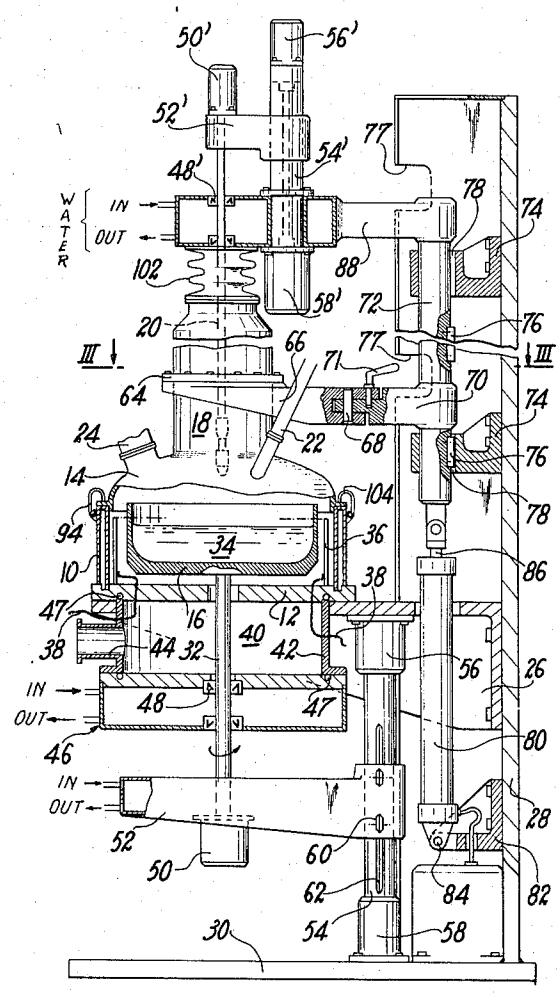
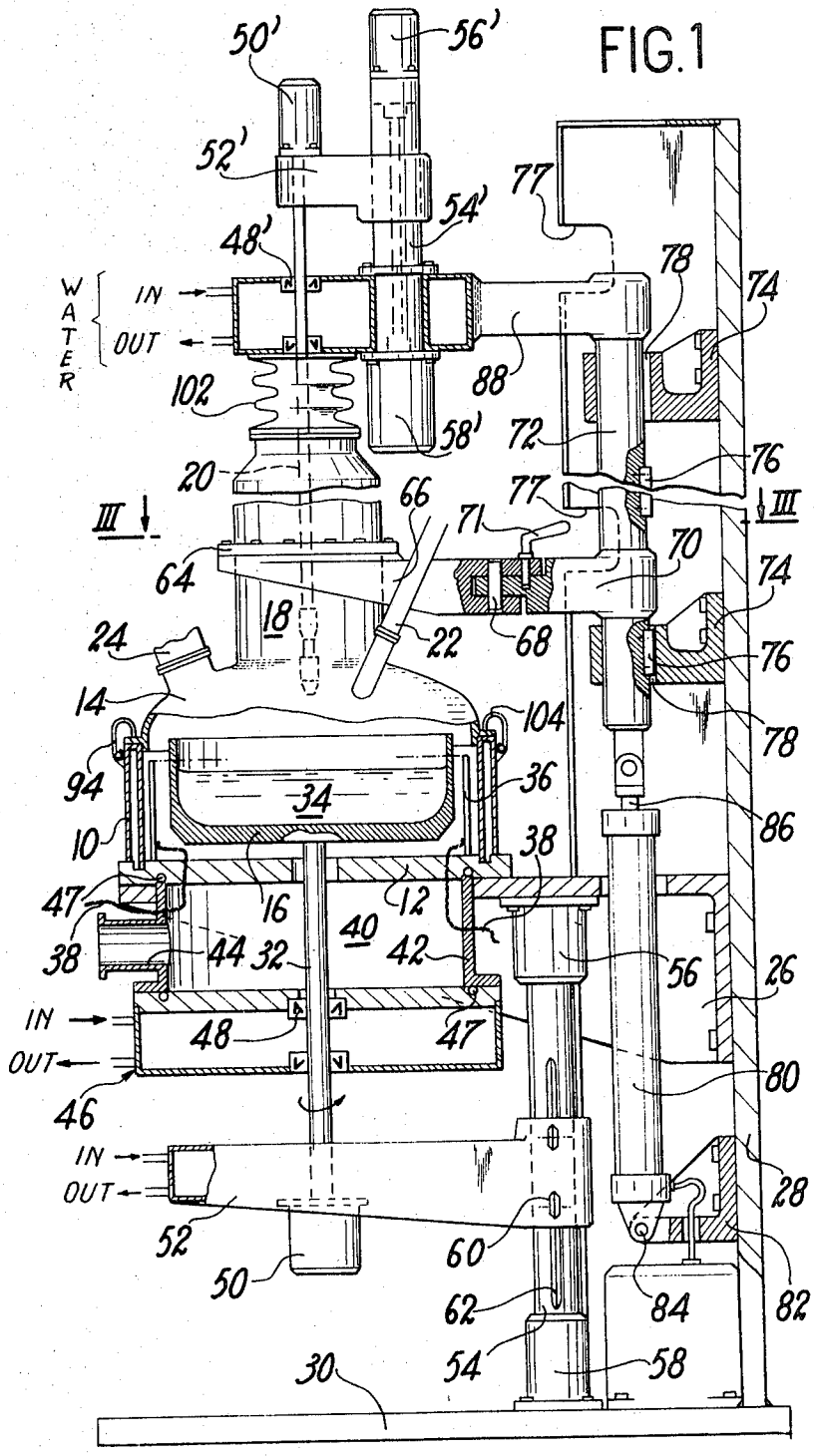


FIG.1


50'
56'
52'
54'
77
48'
78
74
WATER
IN
OUT
88
102
58'
72
76
20
66
77
III
III
71
70
64
74
18
22
68
24
76
14
104
78
94
36
34
86
10
38
47
16
12
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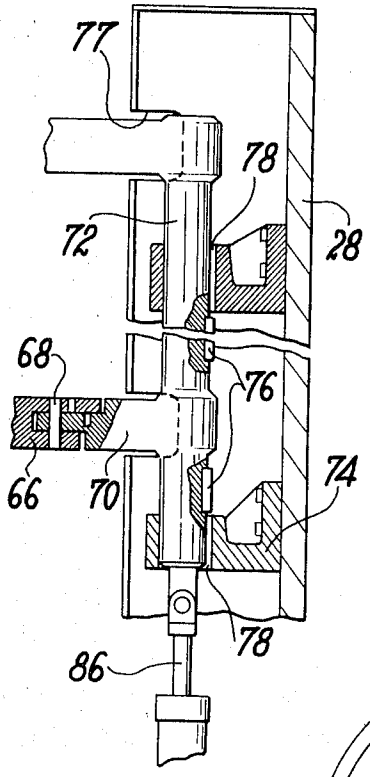
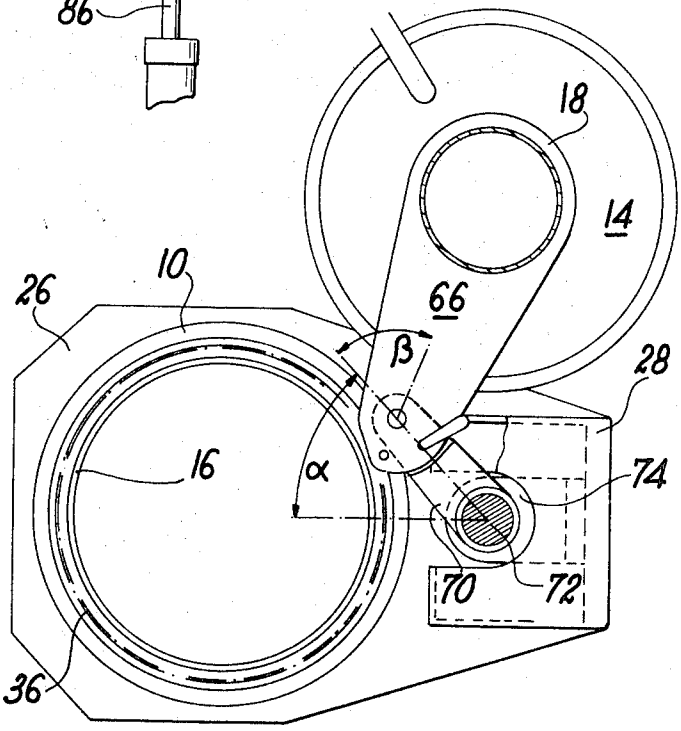


FIG. 2

FIG. 3



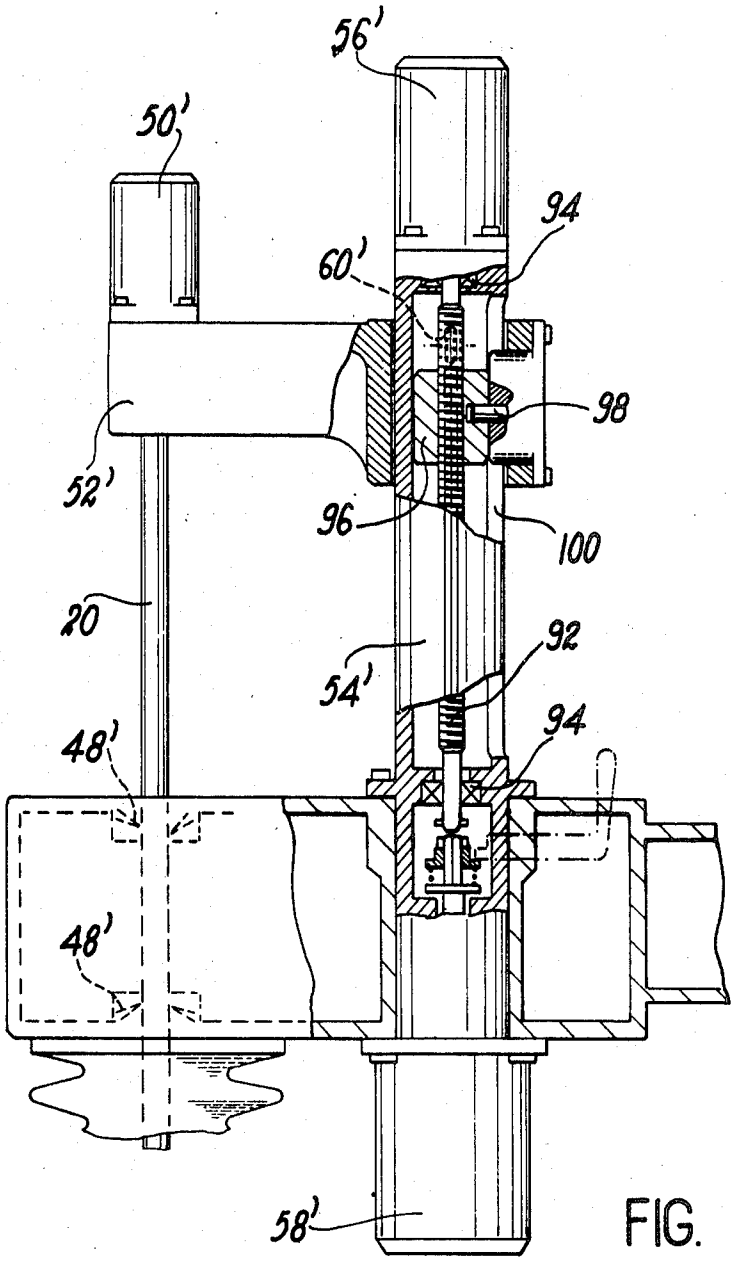


FIG. 4

APPARATUS FOR GROWING CRYSTALLINE BODIES

BACKGROUND OF THE INVENTION

One commonly used method of growing crystals consists of contacting the surface of a melt with a seed crystal and then pulling a monocrystal from the melt. Numerous systems have been developed in the prior art which comprise a leaktight furnace locating a crucible. The crucible is provided with electrical resistance heaters connected to a control device located outside the crucible for maintaining the temperature of an appropriate melt in the crucible at a predetermined value. A vertical rod slidably sealingly projects through the cover of the furnace and is connected to a motor which raises slowly the rod for growing the crystal.

SUMMARY OF THE INVENTION

It is an object of the invention to provide on apparatus which operates to grow a monocrystalline body from a melt and which comprises a furnace consisting of several parts, such apparatus being easier to operate and to maintain than the prior art devices.

According to the invention there is provided an apparatus for growing crystalline bodies comprising: a leaktight furnace for containing a crystal growing melt in a crystal growing environment, said furnace having a tubular body and a cover in which means are vertically movable for pulling a crystalline body from said melt, and support means which includes a side arm secured to said cover and pivotally connected to a lateral extension of a vertical shaft vertically movable between a lower position and an upper position, said shaft being restrained against rotation from an angular position where said cover is aligned with said body by means which are inoperative when said shaft is in an upper position.

The invention will be better understood from a consideration of the following description of an embodiment of the invention given by way of non-limitative example.

The description refers to the accompanying drawings wherein:

FIG. 1 schematically illustrates the apparatus in partial section;

FIG. 2 is an enlarged schematic fragmentary view of the shaft and of the jack assembly of the apparatus of FIG. 1;

FIG. 3 is a fragmentary section along line III—III of FIG. 1 with the cover fully offset laterally;

FIG. 4 is a fragmentary elevation of the seed pulling mechanism, on an enlarged scale and in partial section.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a closed furnace consisting of a generally cylindrical body **10**, a lower plate **12** and a domical cover **14**. The body **10** is double walled and cooling water is circulated in the annular space between the walls during operation. O-rings (not shown) are located between the mating surfaces of the body **10**, lower plate **12** and cover **14** for retaining an appropriate atmosphere within the furnace. The furnace cover is formed with a tubular extension **18** which provides room for vertical movement of a crystal pulling rod **20**. A telescope **22** projecting through the cover is equipped with a calibrated graduated scale which makes it possible to measure the diameter of the crystal as it is being grown from the melt. A loophole **24** closed by a quartz window (not shown) permits to monitor the crystal growth. The lower plate **12** of the crucible is carried by a support bracket **26** securely connected to a vertical frame **28** of channeled cross section (FIG. 3). The frame **28** is carried by a base plate **30** which supports the whole apparatus.

The crucible **16** containing the melt **34** is supported on a rod **32** which is vertically movable through an opening in the lower plate **12**. The melt **34** is heated by electrical resistors **36** surrounding the crucible **16** and whose terminals **38** project out of the lower plate for connection with a control apparatus associated with suitable temperature sensors (not shown).

A plenum chamber **40** is formed under the lower plate **12** for receiving the atmosphere to be maintained in the furnace.

Chamber **40** is limited by the lower plate **12**, a ring **42** having a gas inlet **44** and a sealing assembly **46**. Stationary O-ring seals **47** are located between the mating surfaces of the ring **42**, lower plate **12** and sealing assembly **46**. A pair of lip seals **48** carried by the two walls of assembly **46** provide a sliding fluid-tight connection between the assembly **46** and the rod **32** which projects out of the assembly. In the embodiment illustrated in FIG. 1, the assembly **52** includes a water box provided with an inlet and an outlet for cooling water.

The rod is secured to the shaft of a low-speed rotary motor **50** which rests on a vertically movable support **52**: as a result, the crucible **16** and rod **32** are carried by the support **52** and vertical movement of the latter permits to adjust the height of the crucible and the level of the melt in the furnace.

The mechanism for raising and lowering the support **52** comprises a vertical column **54** mounted between the base plate **30** and bracket **26** by suitable means such as screws or bolts. A rotatable axial screw (not shown) retained against axial movement in the column **54** may be rotated either by a low-speed motor **56** or by a high-speed motor **58**. The support **52** is provided with a sleeve which carries rollers **60** received in an axial groove **62** of the column, thereby providing a splined connection, and with a rotatable nut threaded on the screw: as a consequence, rotation of either motor results in upward or downward movement of support **52** and crucible **16**.

The cover **14** and extension **18** may be lifted and rotated by an assembly which also supports the seed pulling mechanism, as will appear later. The extension is formed with a radial flange **64** secured to a side arm **66**. The side arm **66** is pivotally connected by a vertical pin **68** in a lateral extension **70** of a vertical shaft **72** (FIG. 1 and 3). A releasable latch **71** normally retains the extension **70** and side arm **66** in alignment. The shaft **72** is guided by bearings **74** secured to the frame **28** and keys **76** carried by the shaft are slidably engaged in keyways **78** of the bearing and retain the shaft **72** against rotation except when the shaft is in the vertical position illustrated in FIG. 2. Vertical movement of the shaft **72** is controlled by an electric jack whose cylinder **80** is connected to a bracket **82** of the frame by a pin **84** and whose piston rod **86** is pivotally connected to the shaft.

As shown on FIG. 1–2, the shaft is free to rotate only after is has been raised from the position which corresponds to closed condition of the furnace by an amount sufficient for the lower key **76** to clear the corresponding keyway **78** (FIG. 2), but smaller than that which would correspond to engagement of the upper key **76** with the corresponding beyway. Angular movement of the shaft when in the location of FIG. 2 is however restrained by the size of openings **77** in the stationary frame **28** to a predetermined angle α (FIG. 3). The angle α is so selected as to correspond to a location of the cover for which the seed pulling mechanism is laterally displaced beyond the body of the crucible, making it possible to withdraw the crystal by separating it from the mechanism and removing it downwardly.

The components of the seed pulling mechanism (FIG. 1 and 4) are similar to those of the mechanism for rotating the crucible and moving it vertically. The seed pulling rod **20** has a terminal chuck (not shown) and projects through a water-cooled sealing assembly provided with lip seals **48'**. The rod is supported by a rotating motor **50'** carried by a support **52'**. The support **52'** is adapted to be raised and lowered by a screw and nut connection actuated either by a high-speed motor **58'** or by a low-speed motor **56'** carried by a transverse arm **88** of the shaft **72**. The screw **92** is retained against axial movement in column **54'** by bearings **94** while the nut **96** is connected by a pin **98** to a sleeve integral with slide arm **52'** and slidably non-rotatably engaging the sides of a longitudinal slit **100** of the column. Metal bellows **102** provide a flexible gastight connection between the upper opening of the tubular extension **18** and the sealing assembly.

In order to grow a crystalline body, the crucible **16** is charged with an appropriate melt while the furnace is in the

open condition illustrated in FIG. 3. The furnace is then closed. For this purpose, the cover **14** and the tubular extension **18** are rotated about pin **68** until the side arm **66** and lateral extension **70** are in aligned condition. The latch **71** is inserted and locks the side arm **66** and lateral extension in aligned relationship. The shaft **72** is rotated in turn to the angular position of FIG. **2** for which the cover **14** confronts the body **10**. The lifting jack is deactivated and the shaft **72** moves down along with cover **14**. During that movement, the lower key **78** engages the corresponding keyway **76** thereby guiding the cover into accurate engagement with the upper surface of the body. Fast action fasteners **104** are then locked manually to retain the cover.

The furnace is purged and an appropriate atmosphere is admitted into the furnace through inlet **44**. Such inert gases as nitrogen, argon and helium are generally used although in certain cases a chemically reducing atmosphere or a vacuum may be preferable. The electrical resistance heater **36** is then energized until the charge in crucible **16** is melted and a suitable temperature is attained.

From this point on the sequence of operation is conventional. It may however be noted that during the crystal growing operation the melt **34** is continuously rotated by motor **50** and the interface is maintained at a substantially constant level using the low-speed motor **56**. The rod **20** is also rotated by motor **50'** and slowly lifted by the low-speed motor **56'** which permit to adjust the speed of growth of the crystal; on the contrary the high-speed motors **58** and **58'** are used for movement of the crucible and rod prior to initiation of the crystal pulling step.

When a crystal body of sufficient length has been pulled, contact is broken between the body and melt by an increase of the speed of pull for a short time duration. The pulling mechanism is deactivated until the crystal has cooled down. Access may be gained to the crystal for removal thereof by energization of the jack **80** for lifting the shaft **72** from the position of FIG. **1** to the position of FIG. **2**. The cover crystal pulling mechanism and shaft **72** are then rotated about the shaft axis by an angle α thereby bringing the crystal to a position making it possible to remove it downwardly without interference with the body of the furnace. Care is of course to be taken to avoid that the lower end of the crystal projects down to a level below that of the upper surface of body **10**. If in addition the crucible and/or the inner surface of the furnace are to be cleaned, access may be had to them after the cover has been rotated about pin **78** by an additional angle β (FIG. **3**). This may be done after the latch **71** has been removed.

Although a single embodiment of the invention has been illustrated and described in full detail, it will be apparent to those skilled in the art that numerous modifications are possible. It should be understood that the invention is not limited to the preceding description, but only by the appended claims.

We claim:

1. An apparatus for growing crystalline bodies comprising:
- a leaktight furnace for containing a crystal growing melt in a crystal/environment, said furnace having a tubular body and a cover,
- means vertically movable in said cover for pulling a crystalline body from said melt,
- and support means for said cover, said support means including:
  - a side arm secured to said cover,
  - a vertical shaft having a lateral extension pivotally connected to said side arm, and vertically movable,
  - and means for preventing said shaft from rotating from an angular position where said cover is vertically aligned with said body, said means being inoperative when said shaft is at a predetermined level for which said cover is out of engagement with said body.

2. An apparatus according to claim **1**, including means for limiting the extent of pivotal movement of said shaft when in said predetermined position.

3. An apparatus according to claim **2**, wherein the extent of angular movement of said shaft is just sufficient for the crystal pulling mechanism to clear the body laterally.

4. An apparatus according to claim **2**, having manually releasable locking means for retaining said lateral extension and side arm in aligned condition.

5. An apparatus according to claim **4**, having means for restraining pivotal movement of said side arm to an extent just sufficient for the cover to clear said body upon combined pivotal movement of said sode arm and shaft.

6. An apparatus according to claim **1**, including a splined connection between said shaft and a stationary frame, said connection being inoperative when said shaft is at said predetermined level.

7. An apparatus according to claim **1**, wherein said shaft carries said crystal pulling means.

8. An apparatus according to claim **1**, having a crucible in said furnace, a vertical rod slidably sealingly projecting through a bottom assembly of said furnace, motor means for rotating said rod and crucible, and motor means for moving said rotating means, rod and crucible vertically as a whole.

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