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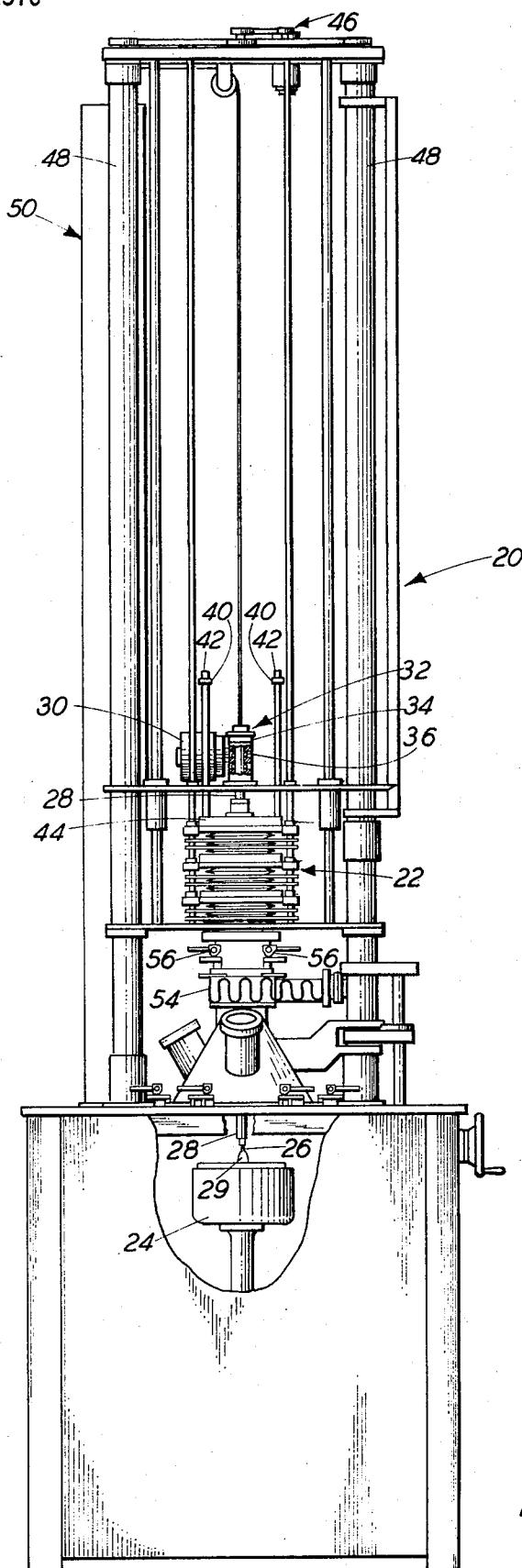
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CRYSTAL GROWER WITH EXPANDABLE CHAMBER

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FIG-1



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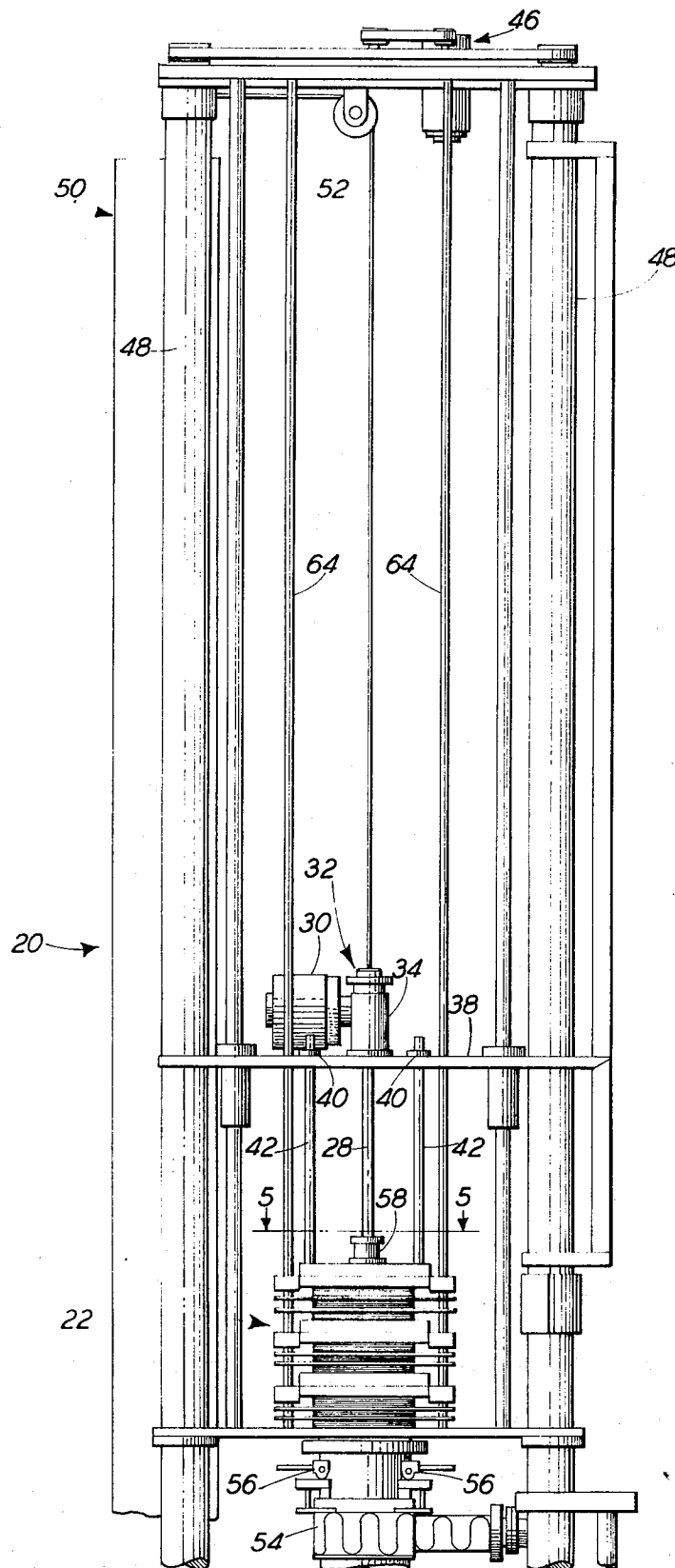
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FIG-2



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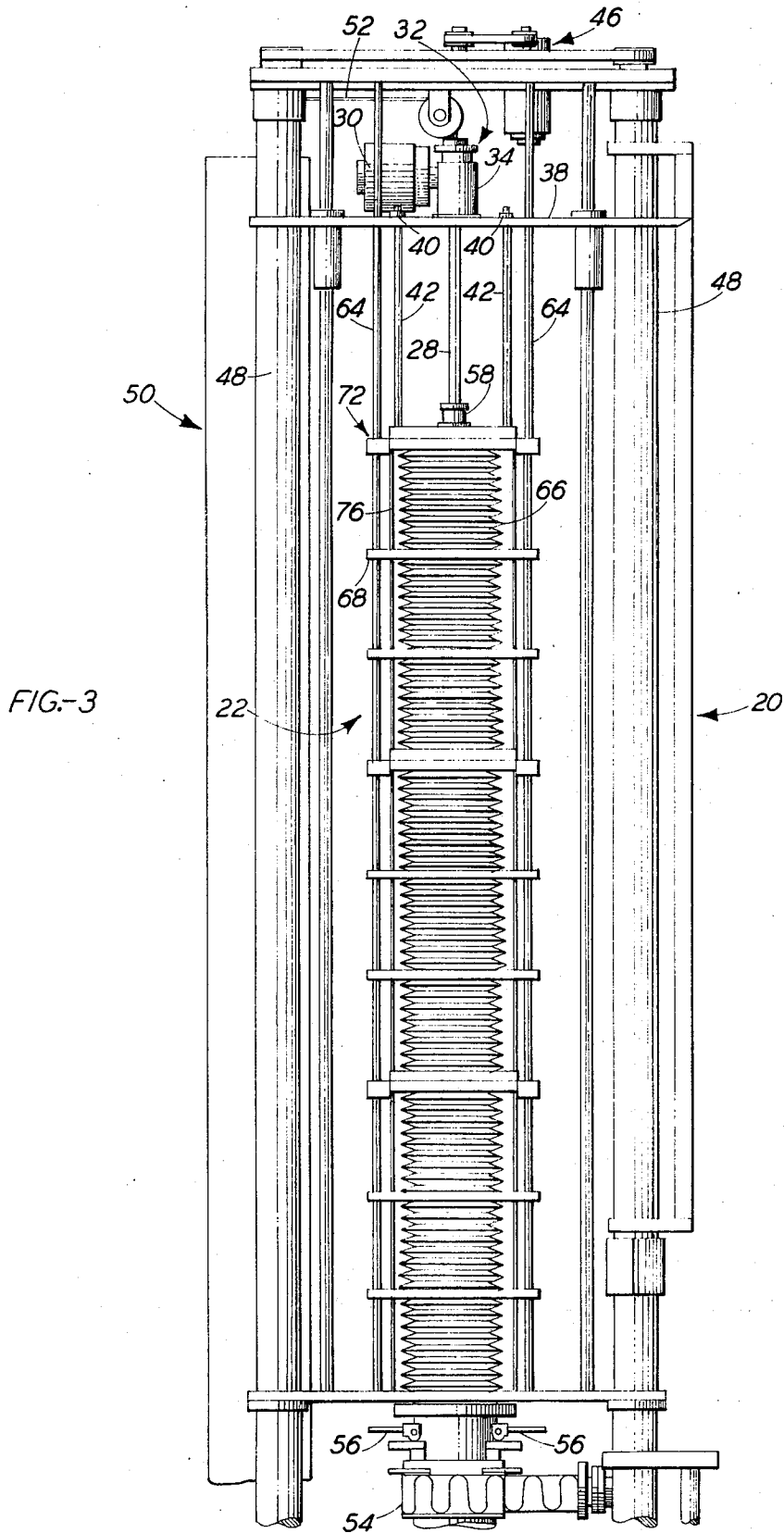
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CRYSTAL GROWER WITH EXPANDABLE CHAMBER.

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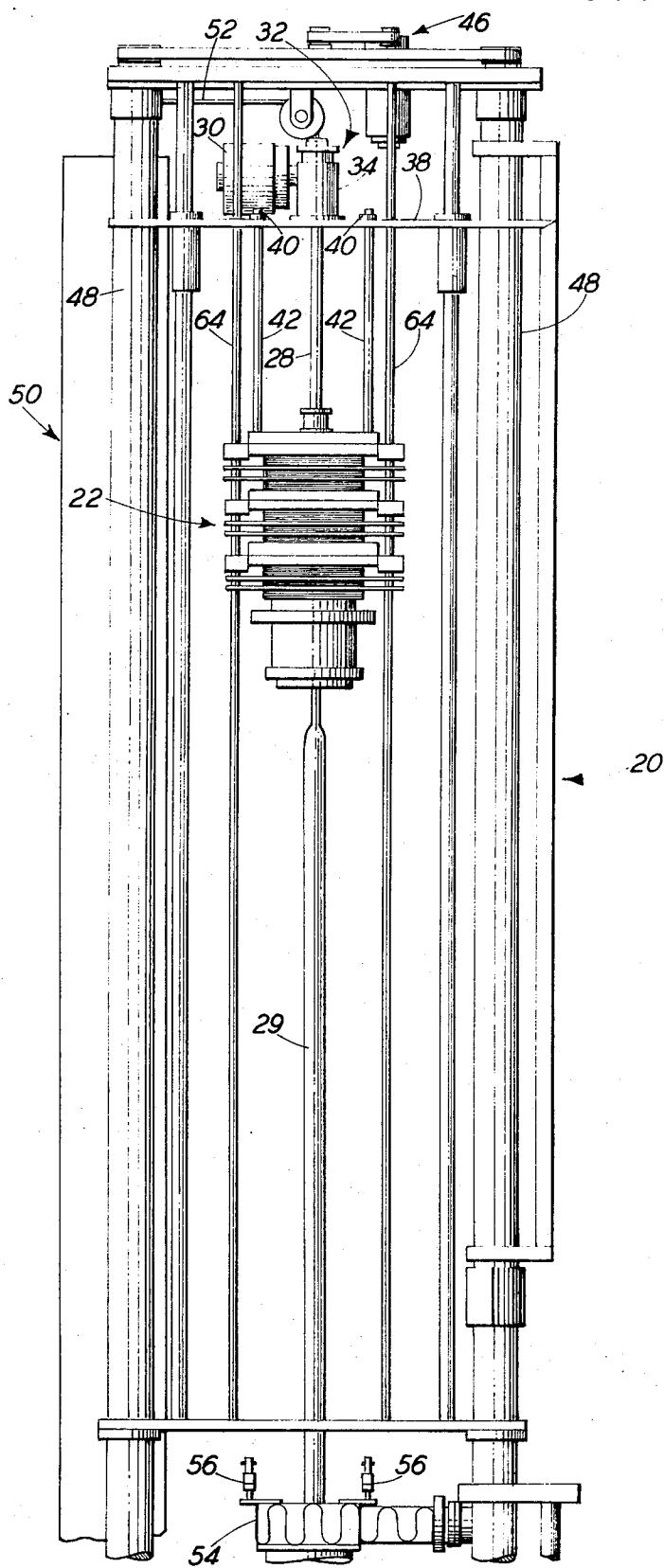
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FIG.-4



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FIG-5

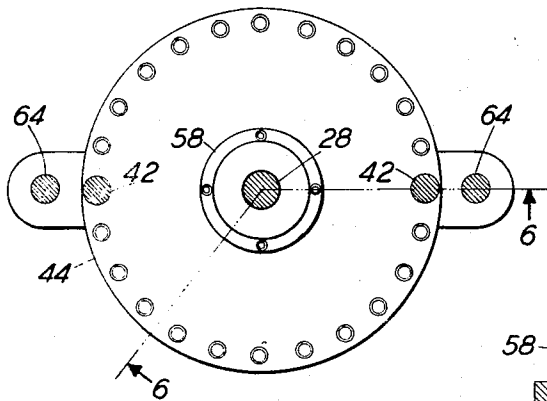
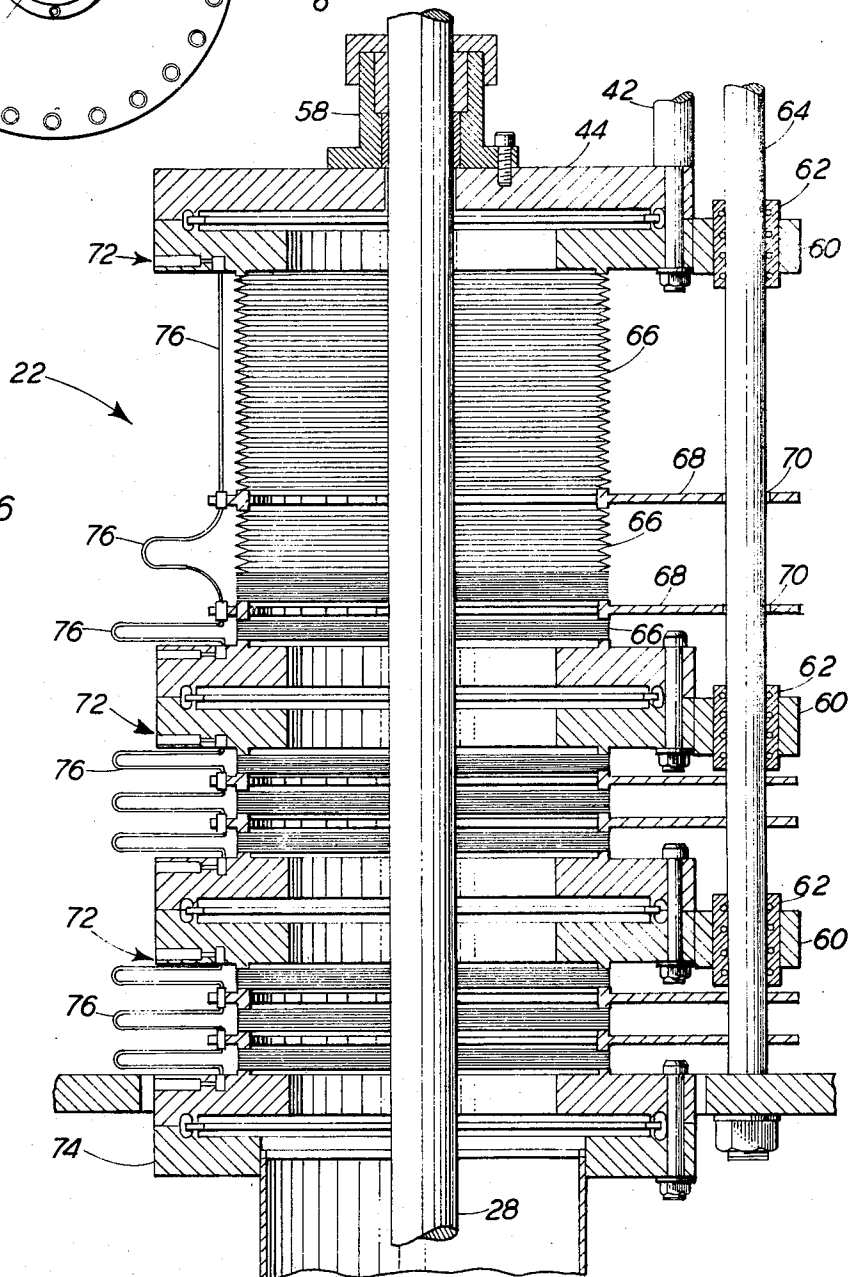


FIG-6



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CRYSTAL GROWER WITH EXPANDABLE CHAMBER

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6 Claims

ABSTRACT OF THE DISCLOSURE

A crystal grower has an expandable chamber formed of alternate bellows and flanges, which surround a portion of a rotatable seed shaft. As a crystal is drawn out of a melt at the end of the seed shaft, the bellows extend to expand the chamber at the same rate the shaft is moved. As a result, an increased length of crystal is achieved for a particular length of seed shaft. A shorter seed shaft results in a more compact grower which ultimately results in fewer crystal defects because of a decrease in probability of shaft run-out or wobble.

The chamber has externally mounted alignment members to withstand adverse environmental conditions which might otherwise cause distortion of the chamber.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to an improvement in crystal growing apparatus wherein extraordinarily long crystals can be grown for a given length of seed shaft. More particularly, the invention relates to a crystal grower with an expandable chamber to surround the seed shaft and methods of using the grower.

Description of the prior art

In crystal growers of the Czochralski type it has long been considered desirable to pull crystals of larger and larger mass from a single run. However, increase in mass of the crystal can result only from increase in diameter and/or increase in length of the final crystal. Both diameter increase and length increase have been explored as possible techniques for increasing crystal mass.

While advances are being made in the area of diameter increase, increases in length are limited by the present need for seed shafts that must be considerably longer than the length of the final length of the crystal. Prior art seed shafts must exceed the length of the crystal because in prior art growers a crystal is pulled into a rigid chamber of controlled atmosphere. A seed shaft must be of sufficient length to extend through the entire length of the rigid chamber and into a melt below.

Increases in crystal length from prior art growers have been achievable only by lengthening both the rigid chambers and the seed shafts. However, such lengthening results in higher probabilities for run-out or wobble of a seed at the end of the seed shaft. With such run-out or wobble comes increased opportunity for crystal defects, an obviously undesirable condition.

Longer seed shafts also result in taller machines and many manufacturing locations have limiting ceiling heights. Thus, lengthening of crystals has, in some cases, been limited by the overall height of grower that can be accommodated in a manufacturing location.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide apparatus for growing extraordinarily long crystals with a given length of seed shaft.

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This and other objects of the invention can be achieved by utilizing a crystal grower with an expandable chamber of a controlled atmosphere into which a crystal is drawn.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of the present invention will be more readily understood from the following detailed description of specific embodiments thereof when read in conjunction with the appended drawings in which:

FIG. 1 is a front elevation view of the inventive crystal grower with portions thereof removed for purposes of clarity;

FIG. 2 is a front elevational view of an upper portion of the grower of FIG. 1 showing a platform raised and engaged with adjustable collars;

FIG. 3 is a view of the apparatus of FIG. 2 with the platform raised further and a chamber expanded;

FIG. 4 is a view of the apparatus of FIG. 3 with the chamber compressed to facilitate removal of a crystal;

FIG. 5 is a sectional view taken along the lines 5—5 of FIG. 2 of a chamber portion of the crystal grower; and FIG. 6 is a sectional view taken along the lines 6—6 of FIG. 5 of the expandable chamber of the inventive crystal grower shown in a partially expanded state.

DETAILED DESCRIPTION

Illustratively, the invention is described in connection with a crystal grower having an expandable chamber formed of bellows. However, it is to be understood that many expandable chamber arrangements can be used to achieve the purposes of the invention.

FIG. 1 is an illustration of a Czochralski-type crystal grower, designated generally by the numeral 20, which embodies an expandable chamber designated generally by the numeral 22 of this invention. As in most typical Czochralski-type crystal growers, material from which a crystal is to be grown is held in a molten state within a heated crucible 24. A crystal seed 26 is held at the end of a seed shaft 28. The free end of the seed 26 is touched to the surface of the molten material in the crucible 24 while the crucible 24 and the seed shaft 28 are rotated in opposite directions. The seed shaft 28 is slowly withdrawn upwardly from the surface of the molten material and a single crystal 29 is thus grown.

The seed shaft 28 is rotated through a drive motor 30 and a pulley arrangement 32. The crucible 24 is rotated through a conventional drive system, not shown, beneath the crucible. The seed shaft 28 is supported in a bearing housing 34 within conventional ball bearings 36. It can be seen that the seed shaft 28 is unsupported for a substantial portion of its length.

In prior art machines the seed shaft was required to be considerably longer than the crystal that was ultimately to be pulled from a melt. Because of the inability to support the seed shafts except at their uppermost ends, the length of crystals which can be pulled by Czochralski machines is limited by the amount of shaft wobble or run-out that can be tolerated before crystal damage occurs. As seed shafts are made longer, the amount of shaft run-out at the free end becomes greater and the probability increases for causing dislocation and imperfections within the growing crystal.

The seed shaft 28 in the inventive machine 20 is not required to be longer than the length of the grown crystal 29 because the chamber 22 into which the crystal is pulled is expandable. The chamber 22 begins to expand when a translation platform 38 engages adjustable collars 40 on shafts 42 which are secured to a top member 44 of the expandable chamber.

The platform 38 is raised through a motor and pulley arrangement, designated generally by the numeral 46,

which drives conventional ball-screw assemblies 48. One example of such an assembly is available from the Saginaw Corporation of Saginaw, Michigan as Model No. 1150-0200 SSL. A counterbalance assembly, designated generally by the numeral 50, is connected through a cable 52 to reduce loading on the ball-screw assemblies 48.

When the crystal 29 is pulled from the melt during the initial period of pulling, the platform 38 is raised without any expansion of the chamber 22. Upon continued upward movement of the platform 38, the collars 40 become engaged with the platform and the chamber 22 begins to expand. The initial engagement is illustrated in FIG. 2.

As the platform 38 continues to move upwardly after engagement with the collars 40, the chamber 22 expands at the same rate that the platform 38 is moved. Thus a controlled-atmosphere chamber becomes enlarged to accommodate the long crystal 29 being pulled at the end of the seed shaft 28 and it can be seen that whatever amount of expansion is provided within the chamber 22 can be added directly in length to the crystal being grown for a given length of seed shaft. For a given set of conditions determined by the amount of seed shaft run-out that can be tolerated, which is of course a direct function of the length of the seed shaft 28, the expandable chamber 22 provides the ability to grow a much longer crystal than that which was available in prior art crystal growing machines.

FIG. 3 shows the machine with the chamber 22 fully expanded. At this point the crystal 29 has been grown to its full length. In normal operation the connection between the crystal and the melt is severed prior to achieving the fully expanded state shown in FIG. 3 and the free end of the crystal 29 is pulled up above a conventional isolation valve 54. One example of such a valve is available from Veeco Instruments, Inc., of Plainview, N.Y. as high-vacuum gate valve No. VA-600. Closure of the isolation valve 54 establishes a separate crucible compartment and permits introduction of normal atmospheric conditions into the expandable chamber 22 without risk of damaging the heated crucible 24 and associated components. After the isolation valve 54 is closed, clamps 56 are released and the bottom of the expandable chamber 22 can be raised as shown in FIG. 4 to expose the grown crystal 29 and facilitate its removal from the end of the seed shaft 28.

One particularly advantageous way of achieving expandability of the chamber 22 is to construct the chamber as a bellows assembly. It is important, however, to construct the chamber 22 in such a way that it remains concentric with the seed shaft 28 and the grown crystals 29 throughout the growing process. The chamber 22 is exposed to rather extreme environmental conditions throughout the growing process. In the case of growing silicon crystals, for example, helium is introduced at the top of the chamber 22 at a rate of 35 standard cubic feet per minute. At this high gas flow rate, it is possible to experience "squirming" or distortion of unrestrained or unsupported bellows assemblies. The chamber 22 is also subjected to partial vacuum at various times during processing and may similarly experience distortion at these times. If the chamber 22 were to distort to the extent of coming into contact with the grown crystal 29, the crystal might very easily break away from the very delicate seed 26 on which it is supported with obviously undesirable results.

It is also important to note that during growth of silicon crystals, silicon oxide films are formed on the inside walls of the chambers of the machines in which they are grown. These silicon oxide films are very brittle and will easily flake away from the surface on which they form. If distortion of a bellows-type chamber were allowed, the silicon oxide film would break away from the surface and drop down into the melt, thus creating a twinning hazard for the growing crystal.

In addition to the high gas-flow rates creating circumstances where the bellows-type chambers might distort, there are situations in which a crystal will be only partially

grown when for various reasons it becomes desirable to stop the growth of that particular crystal and remove it rapidly from the system. In this case, the crystal is quickly drawn up into the chamber without permitting cooling to take place and the chamber is thus exposed to ambient temperatures in the order of magnitude of 800-900° C. This will cause the temperature of the chamber to rise to approximately 300-400° C. Such high temperatures have a tendency to cause distortion of bellows.

For these various reasons it is desirable to have the expandable chamber 22 constructed as shown in FIGS. 5 and 6. The chamber 22 includes the top member 44 onto which a seal unit 58 is mounted. The top member 44 is bolted to a flange 60. The flange 60 is provided with conventional ball bushings 62 available from the Thomson Corporation of Manhasset, N.Y. as Catalog No. A122026. The ball bushings 62 are arranged to slide on alignment posts 64.

Welded to the flange 60 is a bellows 66. One example of a suitable bellows is available from Metal Bellows Corporation of Sharon, Massachusetts and is formed of stainless steel 0.007 inch thick with 28 convolutions per .360 inch length and with an outside diameter of 6.479 inches and inside diameter of 4.979 inches and a stroke of 4 inches. The other end of the bellows 66 is welded to a flange 68. The flange 68 is provided with conventional bronze bushings 70 arranged to slide on the posts 64. Two more sections of the bellows 66 and one more of the flanges 68 as well as a bottom flange 70 are welded together to form a bellows sub-unit, designated generally by the numeral 72. Three of the bellows sub-units are bolted together to form the expandable chamber 22. A bottom member 74 is bolted on the lowermost sub-unit 72 to provide an element onto which the clamps 56 (FIG. 1) engage.

It can be seen that the alternating structure of the chamber 22 with bellows 66 welded to guide flanges 60, 68 and 70 provides a structure which is highly resistant to distortion or "squirming." The alignment posts 64 (see FIG. 1) extend the full length of the desired expansion of the chamber and are mounted concentrically with the center line of the seed shaft 28. Thus as the chamber 22 expands along the guide shafts 64 the chamber is maintained in a highly concentric relationship with the seed shaft 28 and the grown crystal.

The arrangement of the chamber 22 into the three sub-units 72 provides for ease of maintenance in the event of failure of any of the bellows 66. Any one of the sub-units 72 can be quickly unbolted and replaced without extensive welding operations.

Because the bellows 66 are rather delicate and subject to overloading failures, it is desirable to prevent undue stresses from developing in the bellows. The prevention of such stress is achieved by a strain relief cable arrangement incorporated into the structure of the chamber 22. A cable 76 is attached to each of the flanges of one of the sub-units 72. As the chamber 22 expands the uppermost one of the bellows 66 extends until the portion of the cable between the associated flanges becomes taut. The extension of the bellows 66 is thus limited by the length of cable between the associated flanges. After the first length of cable is taut, the second bellows begins to extend. This extension continues until the cable between the associated flanges becomes taut. The loads associated with the weights of flanges is thus transmitted sequentially down through the flanges by the cable 76 and not through the bellows 66.

The overall arrangement of the chamber 22 as shown provides for very high expansion ratios without distortion or squirring. The chamber 22 constructed with the bellows 66 of the example has a compressed length of only 12 inches and a stroke of 36 inches. Thus a 4 to 1 expansion ratio is provided between the compressed length of 12 inches and the expanded length of 48 inches.

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Although certain embodiments of the invention have been shown in the drawings and described in the specification, it is to be understood that the invention is not limited thereto, is capable of modification and can be arranged without departing from the spirit and scope of the invention.

What is claimed is:

1. In a crystal grower having a bellows chamber extensible during operation into which a seed shaft draws a crystal from a melt, and having means supplying a controlled atmosphere to the bellows chamber which might normally deform the chamber completely off its major axis the improvement which comprises:

restraining means independent of the bellows un surrounding relation thereto and intermediate of the ends thereof to prevent distortion of the bellows laterally of the seed shaft.

2. The apparatus of claim 1 wherein the expandable chamber is comprised of alternate rigid flanges and sections of bellows and wherein the rigid flanges are slidably engaged with alignment posts parallel to the seed shaft whereby the chamber is constrained to a position of concentricity about the seed shaft.

3. The apparatus of claim 2 wherein the chamber is comprised of sub-units, each sub-unit having alternate

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flanges and sections of bellows, the sub-units being bolted together for ease of replacement.

4. The apparatus of claim 3 wherein the chamber has an expansion ratio greater than 2 to 1.

5. The apparatus of claim 3 wherein:

the flanges are interconnected with flexible cables, the cables being of a length sufficiently short that they function as strain-relief members for the bellows.

6. The apparatus of claim 5 which further comprises: isolating means for isolating the expandable bellows from the controlled atmosphere of a crucible to create a separate crucible compartment; and means for disengaging the expandable bellows from the crucible chamber to permit compression of the bellows and facilitate removal of a grown crystal.

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