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(54) Selector device for use in the casting of single crystal objects

(57) A selector for use in allowing only one crystal from a directionally-solidified initiating mould cavity (10) to grow into a main casting cavity (12) comprises a ceramic member (16) with a curvilinear groove (18) formed in its surface. The shell mould itself (11) cooperates with the groove (18) to form a curvilinear passage which selects the single crystal required. The cross-sectional shape of the selector is preferably cylindrical but may be otherwise e.g. polygonal. The groove (18), preferably helical, may be formed in the exterior surface of the member (16) or on the interior surface if the member is hollow.

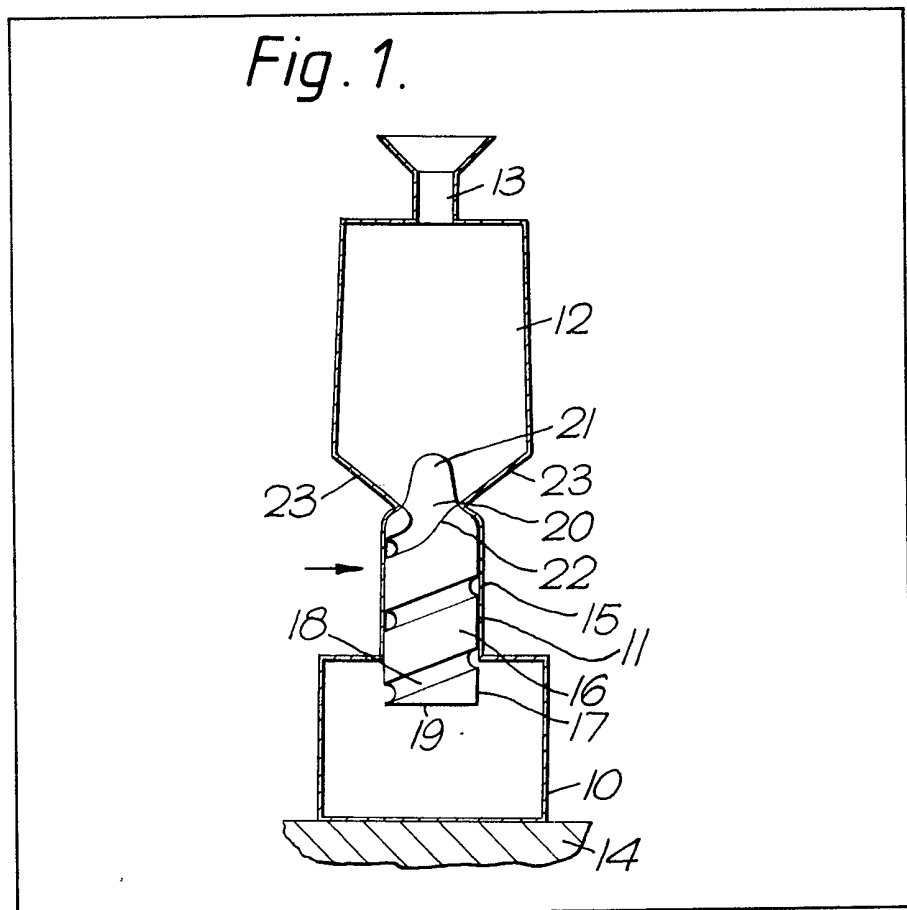


Fig. 1.

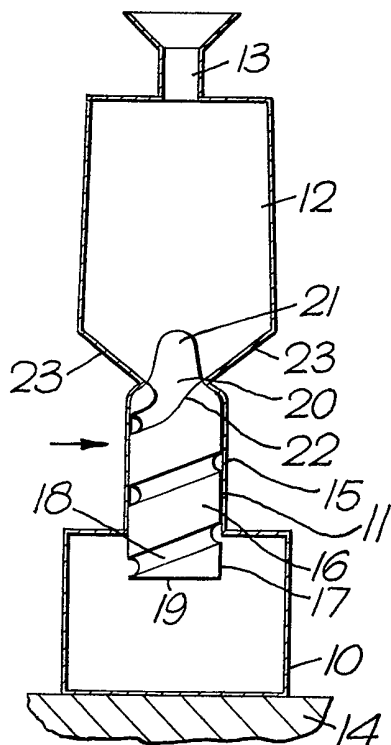


Fig. 2.

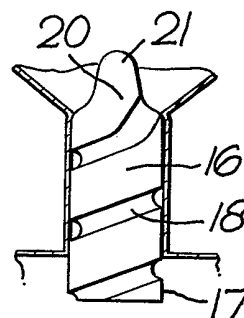


Fig. 4.

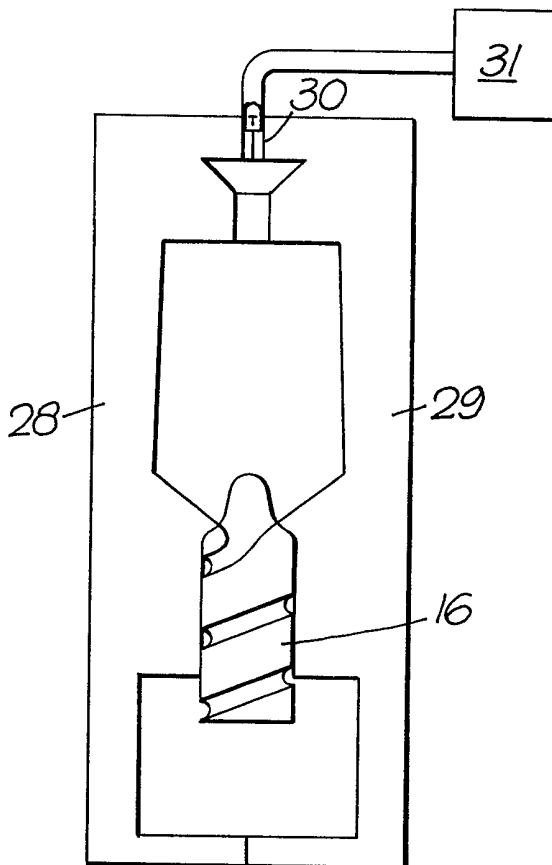


Fig. 3.

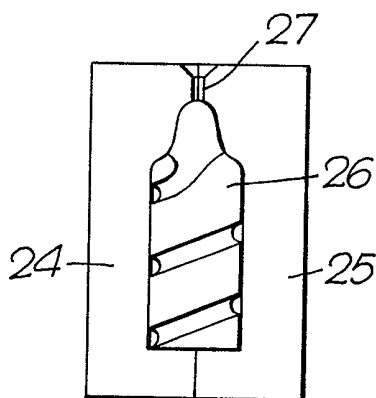


Fig. 6.

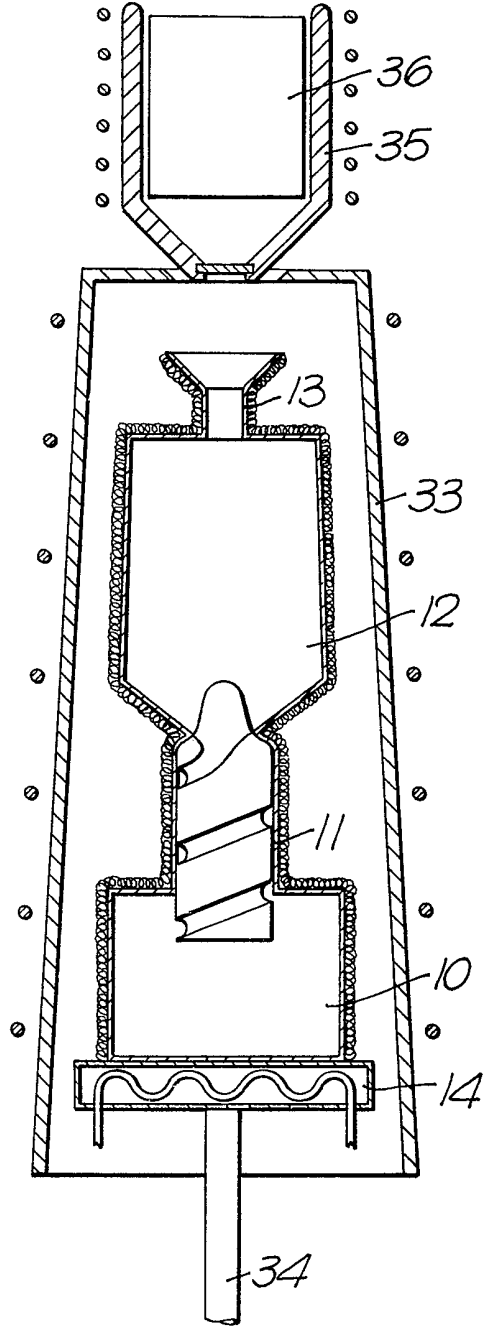
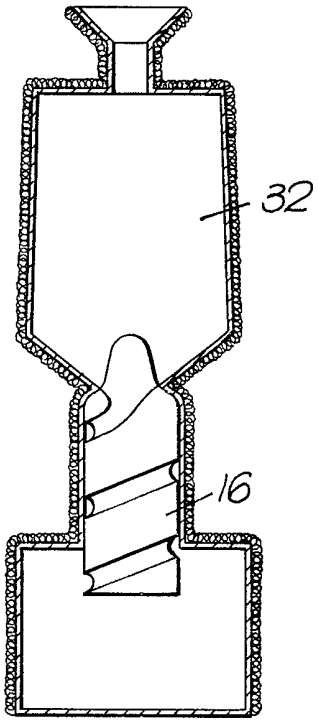


Fig. 5.



## SPECIFICATION

**Selector device for use in the casting of single crystal objects**

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This invention relates to a selector device for use in the casting of single crystal objects.

In recent years casting single crystal objects has become a practical proposition, and the potential advantages of such objects in difficult environments such as the turbine region of gas turbine engines have lead to considerable effort being put into the development of the casting process.

The technique most usually adopted to produce a single crystal casting involves the use of a chill, a mould having initiating and main cavities, a selector device and a directional solidification furnace. The casting process then involves pouring a charge of molten metal to fill the whole of the mould including both cavities and the selector device, and causing the metal to solidify in such a way that the solidification front travels uniformly from the chill and through the initiating cavity, the selector and the main cavity in order.

The directional solidification of the metal from the chill and to the initiating cavity gives rise initially to a columnar grain structure in which the grains of the solidified metal extend unidirectionally away from the chill and toward the selector. When the solidification front reaches the selector, which comprises a relatively narrow passage of curvilinear or helical shape, not all of the columnar grains can continue to grow, and the selector passage is chosen so that only one grain or crystal succeeds in growing through the passage and into the main cavity.

On debouching into the main cavity, the single crystal alone will continue to grow as long as the transition from the selector passage to the main cavity is sufficiently smooth and as long as no other grain initiating irregularities are present. The metal in the main cavity, which is arranged to have the form of the required cast object, is thus caused to solidify as a single crystal of the desired form.

One problem with the apparatus used for this casting process has arisen because of the narrow, curvilinear shape required for the selector passage. The conventional way of providing this passage has been to produce a wax duplicate of the required passage, and to form a shell round this wax duplicate in the normal manner used for lost-wax castings. The shell can then be attached to the initiating and main cavities, or alternatively the wax can be attached to the wax patterns which form the initiating and main cavities and the vanes can be shelled as an integral whole.

Although this technique produces quite satisfactory internal cavities and selector passage, that part of the wax pattern which will eventually define the passage is inevitably narrow and relatively weak and this weakness is compounded by the convoluted form of the passage. Consequently this part of the pattern is prone to damage, in the shelling process and in any handling. It will also be noted that producing the duplicate of the passage is not easy, since this cannot be carried out using a simple

two-part die.

Attempts have been made to solve these problems, using reinforcing means for the selector passage shell or support means for the rest of the shell mould. However, these have tended to be complex, increasing the cost of what is already a relatively expensive process.

The present invention provides a selector of simple form which is relatively strong.

According to the present invention, a selector device for use in single crystal casting comprises a ceramic member having a curvilinear groove formed in its surface, the curvilinear groove opening smoothly out at one extremity of the selector and co-operating with a transition piece, formed at said extremity of the selector, to provide a smooth increase in the cross-sectional area of said passage.

The ceramic member may be solid and cylindrical, in which case the groove is preferably of helical form extending on its outer surface between the extremities of the ceramic member.

In another aspect the invention comprises a mould for single crystal casting incorporating a selector which comprises a ceramic member having a curvilinear groove formed in its surface. The mould then preferably has a portion which overlaps the groove to form, in conjunction with the groove, a curvilinear selector passage. Again, the ceramic member may be substantially cylindrical.

The mould preferably defines an initiating cavity and a main cavity interconnected by said curvilinear passage, the initiating cavity being constructed and arranged to be placed in thermal contact with a chill.

The invention also includes a method of making a single-crystal casting using the selector and/or mould as set out above.

The invention will now be particularly described, merely by way of example, with reference to the accompanying drawings in which:-

*Figure 1* is a partly broken-away view of a mould and selector in accordance with the invention,

*Figure 2* is a view of the selector of *Figure 1*, taken on the arrow 2, and

*Figures 3-6* inclusive illustrate, steps in the method of manufacture and use of the mould and selector of *Figures 1* and 2.

In *Figure 1* there is shown a shell mould consisting of an initiating cavity 10, a selector portion 11 and a main cavity 12. The main cavity 12 has a sprue passage 13 for the entry of molten metal, while the initiating cavity 10 has its bottom face open and sits upon a chill shown at 14.

The selector portion 11 comprises a hollow shell having a substantially cylindrical inner surface 15 within which a ceramic selector device 16 fits closely. The selector 16 consists of a ceramic member having a substantially cylindrical outer surface 17 in which is formed a helical groove 18. The groove 18 extends from the lowermost extremity 19 of the selector 16 to the uppermost extremity 20. At the extremity 20 the selector 16 is provided with an integral transition piece 21 in the form of a rounded projection from the top of the selector.

It will be seen that the lower portion of the selector 16 extends into the initiating cavity 10, and that

where the selector is engaged within the portion 11 of the shell mould the helical groove 18 is overlaid by the wall of the portion 11 to form a helical passage extending from the initiating cavity 10 to the main cavity 12. At its upper extremity the passage formed between the groove 18 and the wall of the shell portion 11 increases smoothly in cross sectional area by virtue of a widening of the groove itself at 22 followed by the debouching of the passage into the main cavity 12. At this point the main cavity 12 has a tapered section formed by sloping walls 23, and in conjunction with the rounded transition piece 21 the transverse area of the mould is caused to increase smoothly from that of the passage to the full cross section of the main cavity 12. The rounded form of the transition piece 21 and the positioning of the walls 23 of the mould, which in effect for extensions of the widened portion 22 of the helical passage, enables a smooth surface to be provided in this region without any grain-initiating discontinuities.

Figure 2 illustrates the selector 16 viewed from the side in relation to the Figure 1 view. Here the shape of this transition piece 21 can be better appreciated, it will be seen that it comprises a rounded or closed projection with one side flattened to form the end portion of the groove 18 as it debouches into the main cavity 12.

There are some features of the mould and selector combination of Figure 1 which should be noted. Thus the sectional area of the mould portion 11 with the selector 16 inside it is relatively large, certainly as compared with the cross section of the helical passage. This means that this part of the mould may be relatively strong, and it will be appreciated that this strength is largely obtained because in our invention the selector passage is formed from a groove in the outer surface of a ceramic member which can be made to have the desired strength. Again, although not essential the substantially cylindrical form of the selector surface allows the use of a helical passage whose form is smoothly curving and which is particularly suitable as a selector device.

Figures 3-6 illustrate how the mould and selector of Figures 1 and 2 is made and used. In Figure 3 are shown the die halves 24 and 25 of an injection moulding machine, the two halves defining a cavity 26 whose shape is that of the selector. It will be seen that the cylindrical overall shape and helical groove of the desired selector enable the use of a two-part die. A sprue passage 27 allows ceramic material to be injected in fluid form to fill the cavity 26, and in the manner of the ceramic cores used to provide cavities in castings the fluid ceramic is arranged to harden due to drying, or the application of heat affecting a thermo-setting resin which is a constituent of the ceramic mix. The hardened ceramic selector may then be removed from the die, dressed as necessary, and fired to produce the final article.

The selector 16 thus produced is then placed in the split die of a further injection machine. This step is illustrated in Figure 4, and it will be seen that the die halves 28 and 29 define between them a cavity whose shape is that of the two cavities and the selector portion of the mould of Figure 2. The

selector 16 is held in the die in the part which will define the selector portion 11 and in what will be its final positioning. A sprue passage 30 is again provided, and molten wax can be injected from an injector device 31 to fill the die cavity, including the helical groove 18 in the selector 16.

It will be noted that in this instance the wax pattern for the two cavities 10 and 12 and the selector portion 11 are made in one piece. We believe that it is desirable to form at least the wax pattern for the selector 11 and the main cavity 12 in one piece to ensure a good transition of the selected crystal into the main cavity. It is not essential to form the pattern for the initiation cavity 10 integral with the selector, and if desired this pattern may be made separately and attached by wax welding or the like to the pattern for the selector. Any undesirable grains nucleated at a less than perfect joint in this position are then selected out in the spiral.

The molten wax is allowed to cool, and thus to set, and the die halves are split to allow the wax pattern 32 thus formed to be removed together with the selector 16 embedded therein. The wax pattern 32 is then dressed if necessary, and is then shelled in a conventional manner to form a casting of ceramic material thereon. The shelling process involves dipping the pattern in a ceramic slurry and stuccoing the dipped pattern with granular ceramic material, this process being repeated until a desired thickness of coating is built up. It may be necessary to perform some specific operation to ensure that the cylindrical surface of the selector 16 adheres to the shell material; for instance it may be necessary to roughen this surface of the selector and/or to remove any wax coating from it.

The shelled pattern may then be fired to strengthen it and to melt out the wax pattern from the shell. A strong shell is thus formed, and at this stage the base of the initiating cavity 10 may be removed to leave it open so that it can be fitted to a chill. Once this step has been carried out the mould plus selector is in the condition as described with reference to Figure 1.

The mould is then assembled to a water-cooled chill 14 and is located within a furnace 33. The chill is mounted on a raising or lowering device 34 so that the mould can be withdrawn from the furnace, and the whole is enclosed in a vacuum chamber (not shown). The device 34 may be electro-mechanical, or hydraulic or pneumatic. At the top of the furnace 33 is mounted a bottom-pouring device 35 of known type, which is provided with a charge of metal at 36.

In operation, the vacuum chamber is evacuated and the furnace operated to heat the mould to a predetermined temperature. The induction heater of the bottom-pouring device 36 is actuated to melt the charge 36, which breaks a fusible plug and falls into the space 13 and thus fills the mould.

With the furnace still operative, the device 34 is operated to withdraw the filled mould slowly downward from the furnace while the water-cooled chill 14 operates to withdraw heat from the bottom of the mould. In this way a solidification front is caused to move evenly up the mould, and the process operates as described above to provide a single-crystal cast-

ing in the main mould cavity 12. The completed casting may then be removed from the mould in the conventional manner.

It will be seen that the cylindrical selector with its helical groove on the outer surface represents a very convenient embodiment of the invention. However, it will be appreciated that the selector could be of various other shapes such as polygonal or even completely asymmetrical in cross-section. Again, it is not necessary for the groove to be formed on the outer surface of the selector; it would be possible to make the selector as a hollow body with the groove formed on its inner surface.

## 15 CLAIMS

1. A selector device for use in single crystal casting comprising a ceramic member having a curvilinear groove formed in its surface, the curvilinear groove opening smoothly out at one extremity of the selector and cooperating with a transition piece formed at said extremity of this selector to provide a smooth increase in the cross-sectional area of said groove.

2. A selector device as claimed in claim 1 and in which said curvilinear groove is formed in an external surface of said ceramic member.

3. A selector device as claimed in claim 2 and in which said ceramic member is of substantially cylindrical shape.

4. A selector device as claimed in claim 3 and in which said curvilinear groove is of helical form.

5. A selector as claimed in any one of the preceding claims and in which said transition piece comprises a rounded projection from one extremity of the ceramic member.

6. A mould for single crystal casting comprising a shell mould which incorporates a selector comprising a ceramic member having a curvilinear groove formed in its surface.

7. A mould as claimed in claim 6 and in which said shell mould has a portion which overlays said groove to form, in conjunction with the groove, a curvilinear passage.

8. A mould as claimed in claim 7 and in which said curvilinear groove is formed in the outer surface of said ceramic member.

9. A mould as claimed in claim 8 and in which said ceramic member is of substantially cylindrical shape.

10. A mould as claimed in claim 9 and in which said groove is of helical form.

11. A mould as claimed in any one of claims 6-10 inclusive and in which said ceramic member comprises a transition piece extending from one of its extremities.

12. A mould as claimed in any one of claims 6-11 inclusive and comprising an initiating cavity and a main cavity interconnected by said curvilinear passage.

13. A mould as claimed in claim 12 and in which said ceramic member is held in a selector portion of the mould extending between said initiating and main cavities.

14. A mould as claimed in claim 12 or claim 13

and in which said initiating cavity is constructed and arranged to be placed in thermal contact with a water-cooled chill.

15. A selector device for single crystal casting substantially as hereinbefore particularly described with reference to the accompanying drawings.

16. A method of making a single crystal using the selector of any one of claims 1-5 inclusive and 15 and/or the mould of any one of claims 6-14 inclusive.

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