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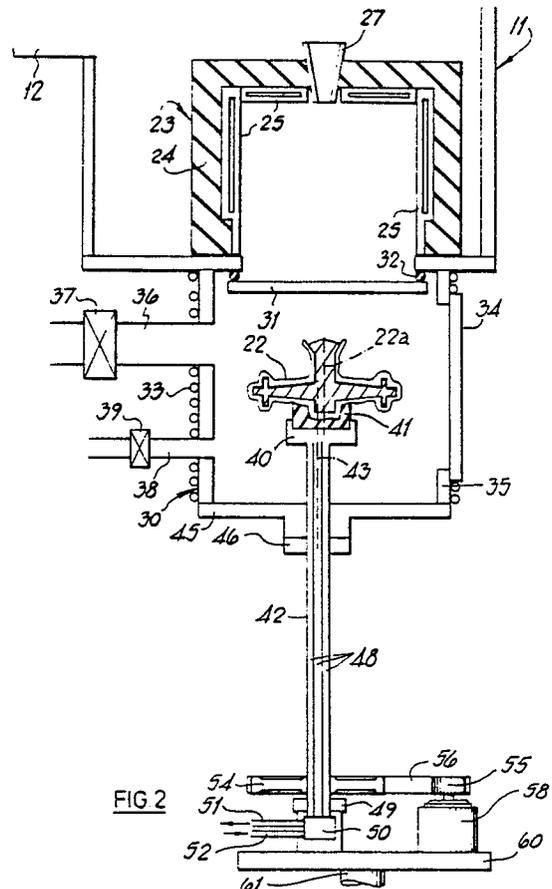
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54 Casting method and apparatus therefor.

57 A method and apparatus are described for the casting of components requiring equiaxed grain structure and low porosity and having widely different section thicknesses. The method comprises the steps of filling a mould (22) of the desired component with molten metal in a first chamber (11), withdrawing the filled mould (22) into a second chamber (34), isolating the second chamber (34) from the first chamber (11) with regard to pressure, pressurising the second chamber (34) with a fluid up to a maximum pressure of 7 MPa and oscillating the filled mould (22) whilst under pressure until at least partial solidification has occurred. Examples of apparatus are given in the casting of turbine discs having integrally formed blades.



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Casting method and Apparatus therefor

The present invention relates to a method and apparatus for casting of articles.

In our co-pending patent application DG55 of even filing date herewith and claiming priority from British patent application No 8712742 filed on 30 May 1987, a method and apparatus are described for the production of cast components having an equiaxed grain structure and reduced levels of shrinkage porosity.

The method comprises casting molten metal into a mould under reduced pressure or under a protective atmosphere in a first chamber and then immediately withdrawing the filled mould containing the molten metal into a second chamber and increasing the pressure in the second chamber with a fluid up to a maximum pressure of 7 MPa until at least partial solidification has occurred. Apparatus is also described for carrying out the method of the invention.

The method and apparatus described in co-pending DG55 is particularly suitable for gas turbine engine components such as blades and nozzle guide vanes, for example, which are cast in gas permeable ceramic moulds. Such components as blades, for example, possess substantial differences in section between the root and airfoil portions which leads, in conventional casting methods for components having equiaxed grain structures, to shrinkage porosity in the thinner airfoil portion.

The method described in co-pending DG55 ensures enhanced feeding of liquid metal to solidifying regions by pressurisation and thus producing reduced levels of porosity.

There is a need, however, to produce components which have very considerable differences in section.

Such components include turbine wheels for gas turbine engines and turbochargers, for example, where a multiplicity of airfoils are cast integrally with a hub or disc portion.

In such components there is not only a problem with porosity in the thinner airfoil portions but there is an additional problem with the grain structure in the hub portion. Because of the generally thick and relatively extensive section of the hub portion large columnar grains tend to grow unchecked. Such grain structures are detrimental to the mechanical properties of the hub which needs to be able to withstand very high forces during operation. An equiaxed grain structure in the hub is highly desirable. It is known to prevent the formation of columnar grains by oscillating the filled mould about an axis eccentric to the component axis. Such oscillation causes mass movement within the solidifying mushy metal and breaks up the

growing metal dendrites before they become too large and firmly set as growing columnar grains. A generally equiaxed grain structure is thus produced.

The method and apparatus of the present invention provide components which have large section differences with both an equiaxed grain structure and reduced levels of porosity.

According to a first aspect of the present invention a method for the production of cast components comprises the step of filling a mould of the desired component with molten metal in a first chamber, withdrawing the filled mould into a second chamber, isolating the second chamber from the first chamber with regard to pressure, pressurising the second chamber with a fluid up to a maximum pressure of 7 MPa and oscillating the filled mould whilst under pressure until at least partial solidification has occurred.

In the case of turbine components cast from iron-, nickel- or cobalt-based superalloys the metal may be cast in the first chamber under reduced pressure or under a protective atmosphere.

Preferably the mould may be preheated whilst in the first chamber rather than preheating in an external preheating furnace. Greater control and flexibility of preheating is obtainable with in-situ preheating by means of, for example, radiant heaters.

Preferably the pressurising fluid may be a gas having little or no chemical reaction with the molten metal. Examples may include argon, helium and nitrogen.

Preferably the pressure may be applied to the filled mould in the mould chamber within 60 seconds of the completion of pouring and more preferably within 30 seconds.

The mould may be oscillated about an axis which is eccentric to the axis of the component being cast.

The mould may be oscillated within a frequency range of from 5 to 500 cycles per minute.

The amplitude of oscillation may lie in the range from 5° to 360° in any one cycle or may be in excess of one complete revolution of the mould.

Frequency and amplitude of oscillation will vary with component dimensions and geometry and furthermore may also vary during the solidification process itself and be affected by the alloy being cast.

According to a second aspect of the present invention apparatus for the production of cast components comprises a casting chamber, metal melting and pouring means, a mould chamber adjacent the casting chamber and connected thereto by

valve means of sufficient size to allow a mould to pass therethrough, mould moving means to move the mould between the casting chamber and the mould chamber, pressurising means for pressurising the mould chamber with a fluid and means for oscillating the mould in the mould chamber.

The casting chamber may also have vacuum pump means associated with it, as may the mould chamber, for producing a reduced pressure within the chambers.

Alternatively or additionally the chambers may be provided with suitable connections for producing a gaseous protective atmosphere such as with argon, for example, within the chambers.

In order that the present invention may be more fully understood an example will now be described by way of illustration only with reference to the accompanying drawings, of which:

Figure 1 shows a schematic section through apparatus according to the present invention prior to casting metal into the mould;

Figure 2 shows part of the apparatus of Figure 1 after casting; and

Figure 3 which shows a section through an alternative construction of apparatus for oscillating the mould.

Referring now to Figures 1 and 2 and where the same features are denoted by common reference numerals. The apparatus is shown generally at 10 and comprises a vacuum casting chamber 11 which includes a port 12 connected to a vacuum pump (not shown). Contained in the chamber 11 is a coil box assembly 13 having induction heating coils (not shown) and crucible 14; the assembly 13 being mounted such that it may be tilted to pour the molten metal 15 in known manner. The chamber also includes a port 16 and vacuum lock 17 to enable the crucible 14 to be recharged with fresh metal whilst under vacuum. In the bottom wall 20 of the chamber 11 is an aperture 21 of sufficient size to allow a mould assembly 22, having an axis 22a, to pass therethrough. Above and surrounding the aperture 21 is a mould heating chamber 23 which comprises an outer insulating box 24 having contained therein known radiant heating means 25 having the appropriate power supply and control means (not shown) attached thereto. In the top of the insulation box 24 is an aperture having a pouring tube 27 therein to guide the molten metal into the mould 22 on pouring. Below the vacuum chamber 11 is a mould chamber 30. The mould chamber 30 is attached in sealed engagement to the bottom wall 20 of the casting chamber 11. The chamber 30 may be isolated from the chamber 11 by means of the isolation valve 31 and seal 32. The valve 31 may be moved between the open position (Figure 1) and the closed position (Figure 2) by suitable known remotely operated control

means (not shown). Cooling passages 33 are provided around the chamber wall. The chamber 30 has a door 34 in the wall to allow positioning and subsequent removal of the mould 22, the door 34 is sealable to the chamber wall 35. Also provided in the chamber wall 35 is a vacuum pumping port 36 connected to a vacuum pump (not shown) via a valve 37. A further port 38 in the wall 35 is provided to supply fluid under pressure from a fluid supply source (not shown) via a valve 39. The mould 22 is mounted on a table 40 but insulated therefrom by an insulation block 41. The table 40 is itself mounted on a movable ram 42 having an axis 43 and which ram may slide in sealed engagement with the bottom wall 45 of the chamber 30 and also rotate or oscillate in sealed engagement therewith. A bearing 46 in the bottom wall 45 supports the ram in both sliding and oscillatory movement. The ram 42 also includes passages 48 for provision of coolant. At the lower end of the ram 42 is a second bearing 49 and a manifold 50 to connect coolant pipes 51, 52 to the ram and allow oscillatory movement. A pulley wheel 54 is mounted on the lower end of the ram 42 and which pulley wheel is drivably connected to a second pulley wheel 55 by a transmission belt 56. The pulley wheel 55 is driven by an electric motor 58 which has appropriate power supplies (not shown) and control means (not shown). The motor 58 and bearing 49 are both mounted on a platform 60 which is itself mounted on a ram 61. The platform 60 may be varied in height relative to the bottom wall 45 of the chamber 30.

In operation the chamber 11 is pumped down to a pressure appropriate to the requirements of the alloy being cast. The valve 31 is closed against the seal 32 and the ram retracted to its position within the chamber 30. The mould 22 is placed and secured on the insulation block 41, the door 34 closed and sealed and the chamber 30 pumped down to a pressure in the region of that in chamber 11. The valve 31 is opened and the ram 42 elevated to move the mould 22 into the mould heating chamber 23. The mould is heated by the radiant heaters 25 to a desired temperature and once at the desired temperature molten metal 15 at a second desired temperature is poured from the assembly 13 into the mould 22 via the pouring tube 27. The filled mould is immediately withdrawn from the chamber 23 into the chamber 30 and the valve 31 is closed against the seal 32 whereupon the valve 37 is closed and the valve 39 opened to pressurise the chamber 30 with fluid such as argon for example. The pressure may be brought to bear against the molten metal in a time of less than 20 seconds and may be raised to a maximum pressure of about 7 MPa. The filled mould 22 is now oscillated about the ram axis 43 at a frequency of

280 cycles/min. and an amplitude of 70°. Since the axis 22a of the mould is eccentric to the axis 43 the metal in the mould in the thicker sections, and which comprises a mixture of liquid metal and growing metal dendrites, is agitated and causes the growing dendrites to be broken up thus preventing the formation of undesirable, coarse columnar grains. The pressure within the chamber 30 assists in the feeding of liquid metal to the solidifying portions to eliminate or minimise the formation of shrinkage porosity. Oscillation frequency and amplitude may be varied during the course of solidification and may only be applied for part of the time required to achieve complete solidification. Similarly the pressure may be released before complete solidification has occurred.

Figure 3 shows an alternative construction of drive for oscillating the mould 22. In this construction the ram 42 does not itself oscillate. Interposed between the ram table 40 and the insulation block 41 is a carrier 70 which is free to rotate on the table 40 supported by a rolling element bearing 71. On the outer periphery of the carrier 70 is a gear toothed ring 72 which, when the ram 42 is lowered to its lowermost extent, meshes with a gear pinion 73 driven by an electric motor 74. The motor 74 is connected to suitable control apparatus (not shown) situated outside the chamber 30.

In the examples given above the article being cast is a turbine disc and blade unit having rotational symmetry. Such symmetry is not necessary as any article which has widely different section thicknesses included therein may be cast by the method and apparatus of the present invention.

Many modifications may be made to the embodiment shown. Such modifications may relate to the type of valve employed to seal the casting chamber from the mould chamber and to the method and precise apparatus used to move the ram and mould between chambers and also the means used to oscillate the mould.

The ram 42 may be elevated by electrical or hydraulic means, for example.

Claims

1. A method for the production of cast components, the method being characterised by comprising the steps of filling a mould (22) of the desired component with molten metal in a first chamber (11), withdrawing the filled mould into a second chamber (30), isolating the second chamber from the first chamber with regard to pressure, pressurising the second chamber with a fluid up to a maximum pressure of 7 MPa and oscillating the filled mould whilst under pressure until at least partial solidification has occurred.

2. A method according to claim 1 characterised in that the filled mould is oscillated within a frequency range of 5 to 500 cycles per minute.

3. A method according to either claim 1 or claim 2 characterised in that the amplitude of oscillation is greater than one complete revolution.

4. A method according to either claim 1 or claim 2 characterised in that the amplitude of oscillation lies in the range of 5° to 360°.

5. A method according to any one preceding claim characterised in that the fluid is selected from the group comprising helium, argon and nitrogen.

6. A method according to any one preceding claim characterised in that the mould is heated in the first chamber prior to filling the mould with molten metal.

7. A method according to any one preceding claim characterised in that the pressure is applied within 60 seconds of the completion of pouring of the molten metal.

8. A method according to claim 7 characterised in that the pressure is applied within 30 seconds of pouring.

9. A method according to any one preceding claim characterised in that the metal being cast is selected from the group comprising aluminium alloys, copper alloys, iron alloys, nickel alloys and cobalt alloys.

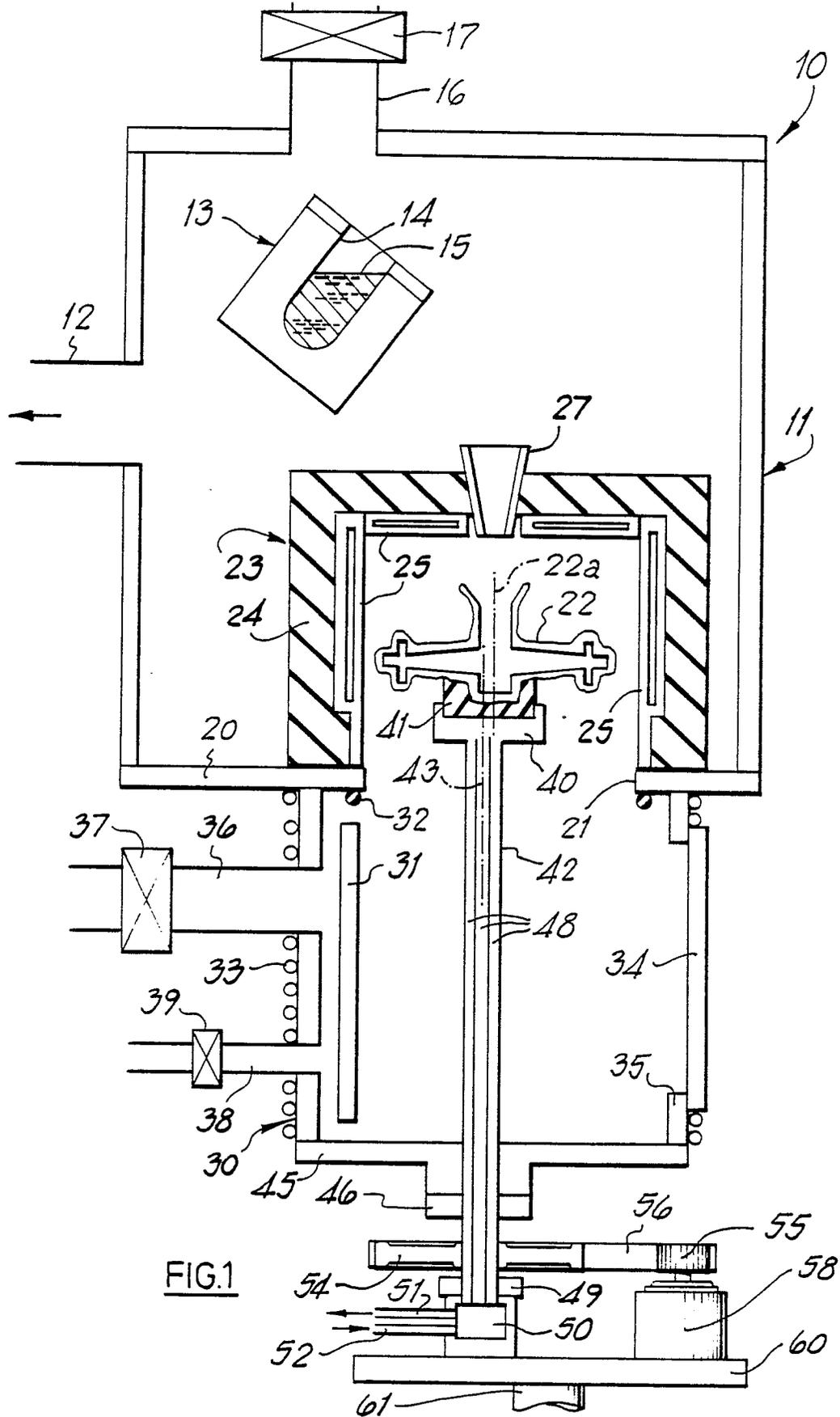
10. Apparatus for the production of cast components the apparatus being characterised by comprising a casting chamber (11), metal melting and pouring means (13), a mould chamber (30) adjacent the casting chamber and connected thereto by valve means (21,31) of sufficient size to allow a mould (22) to pass therethrough, mould moving means (42) to move the mould between the casting chamber and the mould chamber, pressurising means (38,39) for pressurising the mould chamber with a fluid and means (54,55,56,58) for oscillating the mould in the mould chamber.

11. Apparatus according to claim 10 characterised in that the mould axis (22a) and the axis of oscillation (43) are not coincident.

12. Apparatus according to either claim 10 or claim 11 characterised in that the casting chamber and/or the mould chamber are provided with vacuum pumping means.

13. Apparatus according to any one of claims 10 to 12 characterised in that the mould moving means comprises a height positionable ram which is itself oscillatable about its axis.

14. Apparatus according to any one of claims 10 to 12 characterised in that the mould is fixed to carrier means (70) which is supported by the mould moving means (40,42) on bearing means (71) to allow independent rotation thereof.



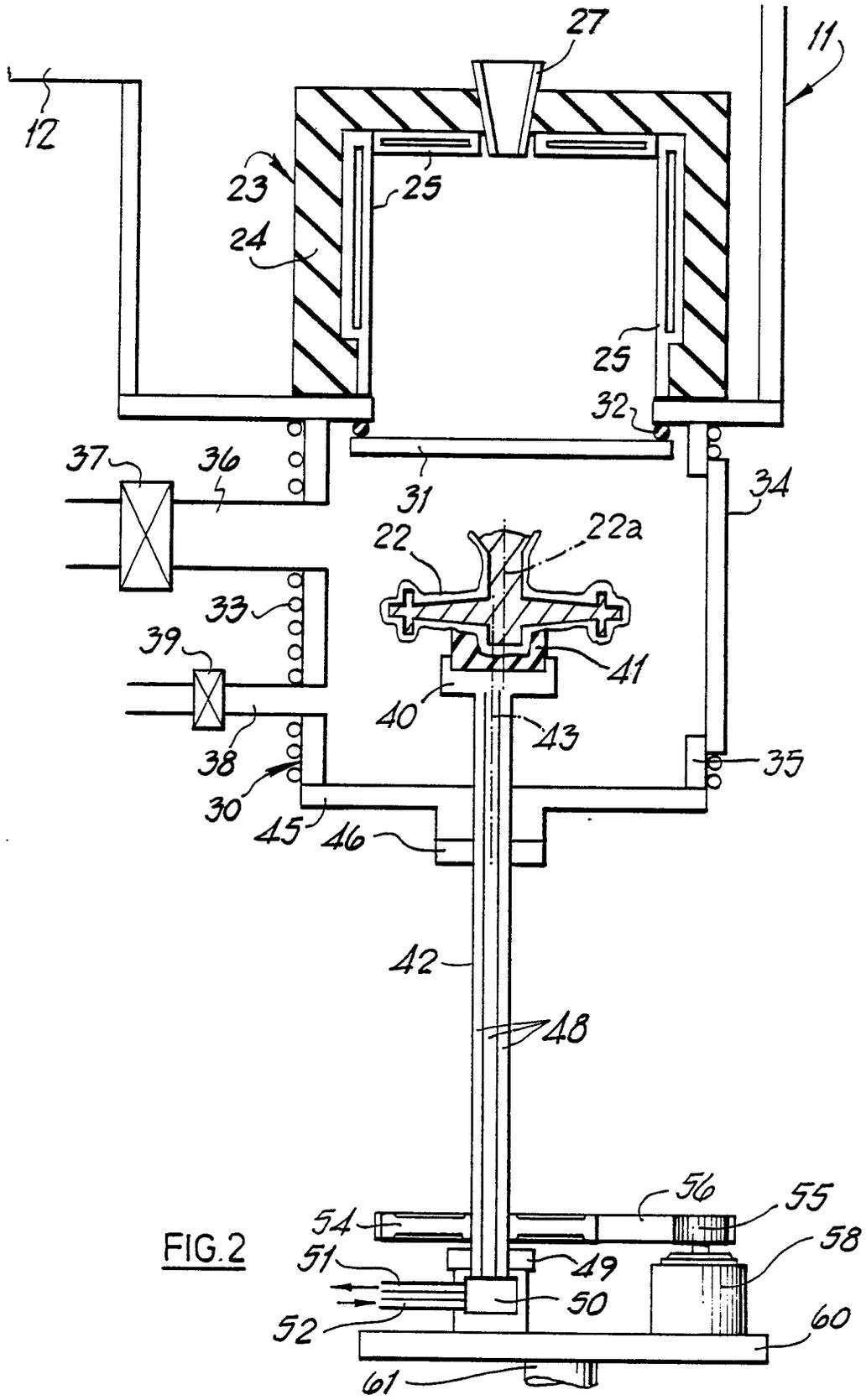


FIG.2

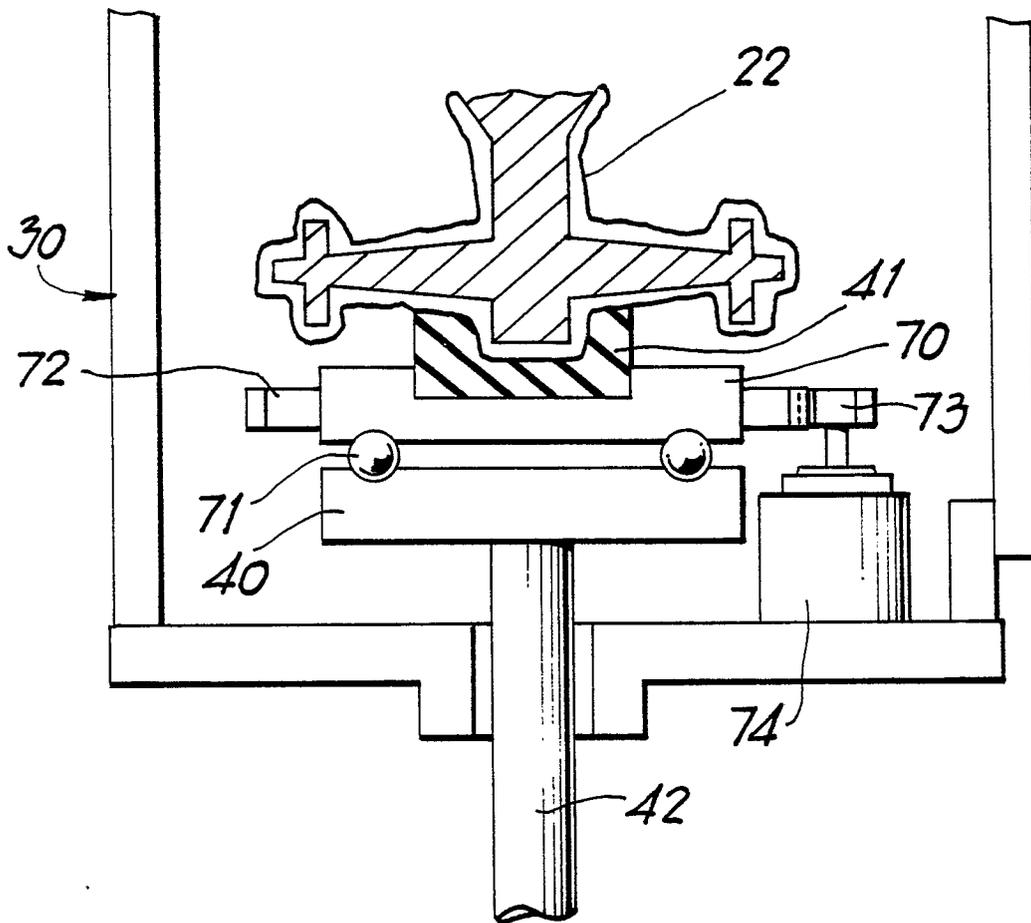


FIG. 3



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
P, Y	DE-A-3 603 310 (LEYBOLD-HERAEUS GmbH) * Column 1, line 64 - column 2, line 68 *	1-2, 4-5 , 9-10, 12	B 22 D 27/13 B 22 D 27/08
Y	GB-A-1 472 288 (TUCHKEVICH et al.) * Page 2, lines 13-29 *	1-2, 4-5 , 9-10, 12	
Y	DE-A-3 220 744 (LEYBOLD-HERAEUS GmbH) * Page 5, lines 14-18; page 8, line 15 - page 9, line 18 *	1, 3, 5, 9 -10, 12	
Y	US-A-3 568 752 (D.C. WILLIAMS) * Claim 1 *	1, 3, 5, 9 -10, 12	
A	GB-A-1 356 890 (LEYBOLD HERAEUS GmbH) * Page 1, lines 15-19; page 2, lines 44-105; page 4, lines 38-43; page 4, lines 127-129 *	1, 9-10, 12	
A	FR-A-2 255 983 (UNITED AIRCRAFT CORP.) * Page 9, line 35 - page 10, line 32; claim 1; page 8, lines 36-40 *	1, 9-10, 12	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 22 D
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05-09-1988	Examiner DOUGLAS K. P. R.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background. O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	