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CENTRIFUGE STABILIZING ASSEMBLY WITH HEAT PROBE

Filed April 15, 1963

2 Sheets-Sheet 1

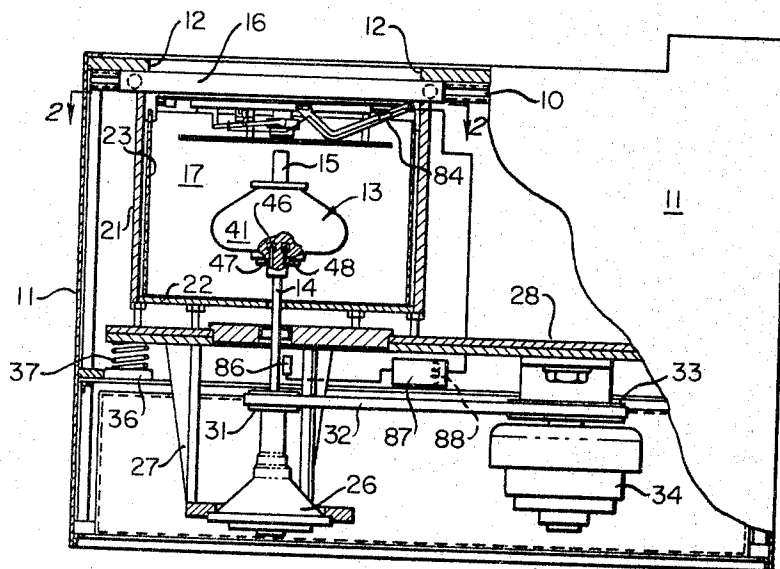


FIG. 1

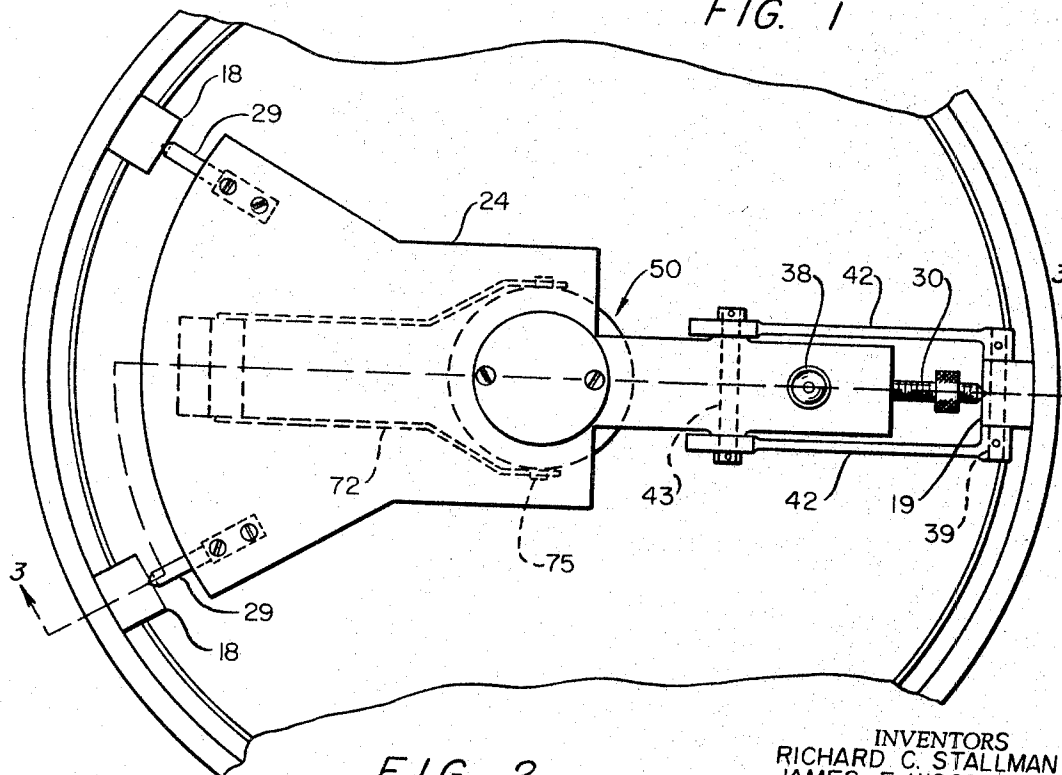


FIG. 2

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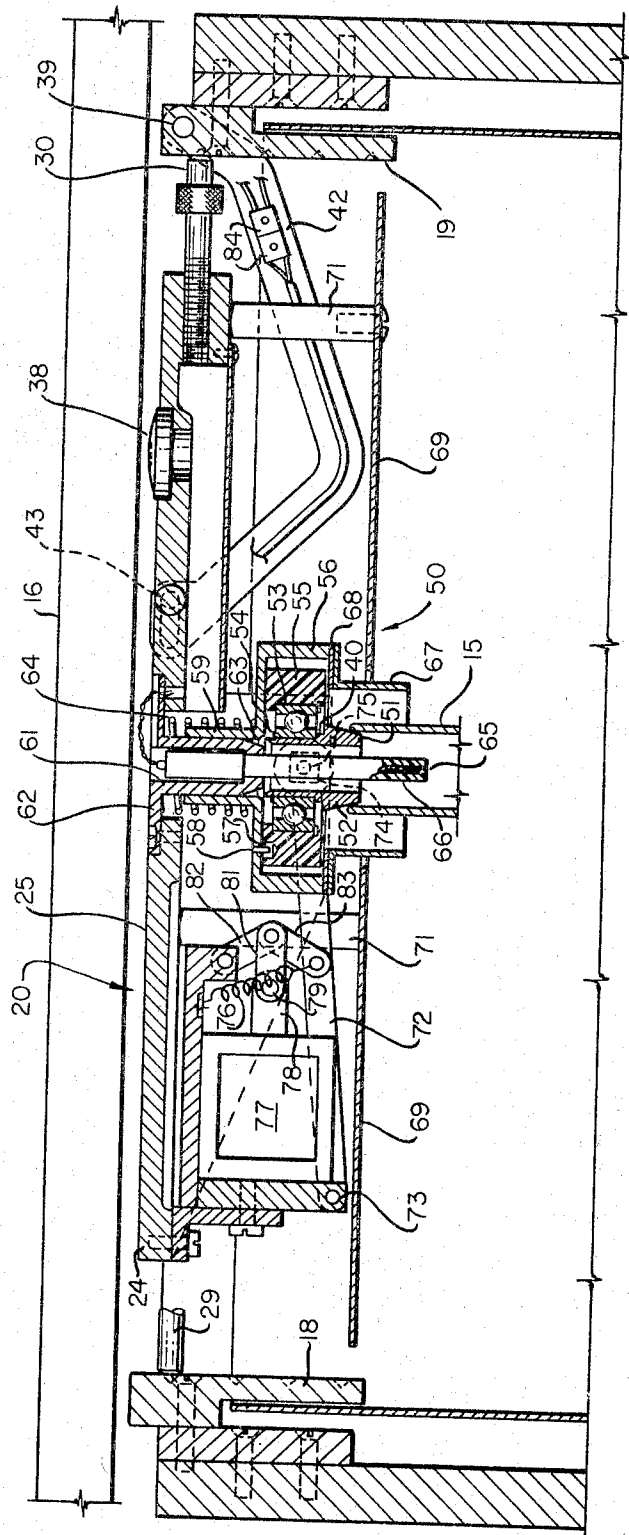


FIG. 3

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3,322,338 CENTRIFUGE STABILIZING ASSEMBLY WITH HEAT PROBE

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9 Claims. (Cl. 233—23)

This invention relates to centrifuge apparatus and more particularly to apparatus for stabilizing centrifuge rotors at low rotational speeds.

In certain high speed centrifuge apparatus a rotor of relatively large size is supported for rotation upon a small diameter somewhat flexible spindle. The spindle is driven at high speed. The small diameter spindle permits the true center of gravity of the combined mass of the rotor and fluid contents to become the axis of rotation. While every effort is made in the manufacture of rotors of this kind to have the true center of gravity of the mass coincide precisely with the geometric center of gravity, there usually will be a slight lateral displacement between the two, particularly when loaded with fluid to be centrifuged.

As the rotor is brought up to speed, and also as it decelerates below a predetermined speed, a noticeable wobbling, or instability, is imparted to the rotor. This wobbling action, if permitted a wide excursion, has the adverse effect of serving to re-mix the sediment obtained by high speed centrifugation. It also causes other objectionable problems. One such problem involves the radiation coupling between a temperature transducer and the rotor.

As is known, rotors of the above type are oftentimes operated at controlled temperatures which must be precisely measured. In one arrangement, in order to measure the rotor temperature an upstanding cylindrical sleeve open at the top, is provided and carried coaxially of the rotor. The inside of the sleeve is blackened to provide a black body surface. A temperature transducer is disposed to extend downwardly into the sleeve and provided with a black body radiation shield therearound in order to form a radiation closure to the upper end of the sleeve. In the past, the upwardly extending sleeve has been necessarily of substantial diameter in order to accommodate the above noted wobbling action of the rotor. By making the sleeve of substantially large diameter the radiation coupling has been rendered more difficult to maintain and accordingly it is desirable to have the radiation coupling effected with a sleeve of as small diameter as possible.

Thus, it is a general object of the present invention to provide an improved rotor stabilizing assembly.

It is another object of the invention to provide an improved stabilizing assembly incorporating a temperature transducer.

A more particular object of the present invention is to provide an improved stabilizing assembly including a physically protected temperature transducer.

In the past means have been provided to stabilize rotors during the transition from low to high speed and vice versa. One arrangement employs means for forcing the rotor to rotate about an axis of rotation fixed with respect to the frame. Whenever this axis of rotation fails to precisely correspond to the true axis of rotation of the rotor through the center of gravity of the mass of the rotor it will be apparent that as the rotor speed increases the rotor will try to shift the axis of rotation laterally over to pass through the true center of gravity. Due to the magnitude of the forces generated by the rotor, the spindle is often damaged by this action.

Therefore, it is yet another object of the present invention to provide a stabilizing assembly wherein lateral displacement of the axis of rotation of the rotor from

the geometric center of gravity to the true center of gravity is accommodated.

These and other objects of the invention will be more readily apparent from the following description of a preferred embodiment when considered in conjunction with the drawing, in which:

FIGURE 1 is an elevation view of a portion of a centrifuge apparatus embodying the present invention;

FIGURE 2 is a plan view of a portion of FIGURE 1, taken along the line 2—2; and

FIGURE 3 is an elevation view of FIGURE 2 taken along the line 3—3.

In the following description, there is provided, as shown in FIGURE 1, centrifuge apparatus including an outer frame 11 which encloses the drive means and rotor housing. The top of frame 11 is provided with an opening 12 through which a rotor 13 may be passed for mounting within a rotor chamber 17 on a relatively small diameter drive shaft or spindle 14, as will be presently described.

Coaxially of and mounted on the top of the rotor 13 a cylindrical sleeve 15 is formed to provide a convenient handle for manipulating the rotor. The interior of sleeve 15 is coated as a black body.

The side walls of rotor chamber 17 include a cylindrical steel member 21 which acts as a guard should the rotor explode under the strain created by the relatively high rotational velocity at which it is operated. The lower end of member 21 receives the bottom wall 22, likewise made of relatively strong material. A liner 23 is mounted inside the chamber 17 proximate the interior surface of the member 21. The interior of chamber 17 is provided with refrigeration means including evaporator coils (not shown) surrounding the liner 23 which serve to control the chamber temperature.

Preferably spindle 14 is made of resilient material and extends downwardly with its lower end journaled in an oil filled bearing assembly 26. Bearing assembly 26 is supported by spaced brackets 27 extending downwardly from a resiliently mounted base 28. Base 28 may be supported from a fixed member 36 by springs 37. A driven pulley 31 is carried by spindle 14 and can be driven by a belt 32 from a drive pulley 33 and motor 34, or can be directly driven by the motor through suitable gearing. Opening 12 is closed by a sliding door 16 supported by rollers carried to move in tracks or ways 10.

In general, rotor means 13 includes a relatively large conical bowl portion 41 including a well 46 adapted to receive the upper end of spindle 14. Spaced pins 47, 48 are adapted to engage accommodating holes formed in the upper ends of spindle 14 to provide a drive connection between spindle 14 and the bottom of bowl 41.

According to the invention, there is provided apparatus for stabilizing the rotor about its axis of rotation through low speeds and for limiting and damping lateral movement thereof with respect to frame 11. The apparatus comprises generally a movable bearing assembly carried by the frame, wherein a rotatable member is supported substantially coaxially of the axis of rotation of the rotor. The rotatable member is formed and adapted to releasably engage the rotor in order to hold same for rotation therewith substantially about the axis of rotation. Means are provided for supporting the rotatable member to move with yielding resistance within predetermined limits laterally of the axis of rotation to permit the rotor to operate about its true axis of rotation through the center of gravity of the combined mass of the rotor and contents and to damp lateral movement of the rotor during critical transition speeds. The rotatable member is movable between advanced and retracted positions to engage and release the rotor and means are provided to automatically respond to transition of the rotor from a given speed

range to another to move the rotatable member between these positions. As further explained below a temperature transducer is carried by the bearing assembly to extend into and in radiation coupled relation with a sleeve on the rotor. The rotatable member is disposed with respect to the transducer to protect the latter from contact with the sleeve of the rotor during lateral damping movements thereof.

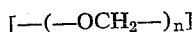
The stabilizing assembly is hingedly mounted to be swung over to extend across opening 12. It can also be moved vertically into and out of chamber 17. The stabilizing assembly is supported with respect to the frame by means of a pair of brackets 18 and a third bracket 19, as will be further described below.

A support assembly 20 includes a Y-shaped bridge member 24 adapted to extend across opening 12 and to have a generally flat upper surface 25. The two arms of the Y each carry a fixed, pointed support pin 29 whereas the stem of the Y carries an adjustable pointed pin 30. Pins 29, 30 are adapted to be received by detents formed in brackets 18, 19, respectively. In order to permit the stabilizing assembly to be positioned lower into chamber 17 for shorter rotors, several detents are formed in each of brackets 18, 19. In order to position bridge member 24 at any selected level in chamber 17, pins 29 are inserted in detents of brackets 18 at a selected level and pin 30 adjusted outwardly into a detent on a corresponding level. To insure a proper orientation of bridge member 24, a liquid level 38 is carried in the upper face of member 24. Therefore, if the bubble in level 38 is not centrally located the operator of the equipment is immediately apprised of the fact that he has mounted member 24 improperly in the apparatus.

Means for pivoting member 24 into and out of opening 12 includes pivot pin 39 carried in bracket 19, and a pair of pivot arms 42 carried at one end therefrom. The other ends of arms 42 are slotted to receive pin 43 carried in member 24. The slotted ends of arms 42 permit member 24 a relatively limited transverse freedom of movement until rigidly secured by means of pins 29, 30.

A bearing assembly 50 depends downwardly from member 24. Assembly 50 includes a depending stabilizing member 51 rotatable substantially coaxially of the geometric axis of rotation of the rotor, and is formed and adapted with an inverted conical exterior surface 52 to releasably, engage sleeve 15 at the upper edge thereof. Member 51 holds the rotor for rotation therewith in general about its geometric axis of rotation, at least as the rotor is started up. Means are provided, however, for supporting member 51 to move with yielding resistance laterally within predetermined limits, to permit the axis of rotation of member 51 to move in an orbit (i.e. revolve) about the true axis of rotation through the center of gravity of the mass of the rotor and its contents thereby damping lateral movement of the rotor during critical transition speeds.

Thus member 51 is carried by the inner race of a ball bearing 53 and locked in place between a snap ring 54 and a shoulder 40. The outer race of ball bearing 53 is similarly carried by an annular bearing housing 55 preferably of a plastic material not requiring fluid lubrication, such as the acetal resin material sold under the trademark "Delrin" manufactured by E. I. Du Pont de Nemours & Co. This material is characterized by the radical



Housing 55 is carried within and laterally spaced from a stabilizer housing 56 and can move laterally thereof. A well 57 of limited axial extent is drilled into the upper surface of housing 55, and disposed to receive registration pin 58 carried by housing 56, so as to prevent relative rotation between housings 55, 56.

Bearing assembly 50 is arranged whereby member 51 is movable between advanced and retracted positions to engage and release sleeve 15. Thus, as noted, member 51

is carried in stabilizer housing 56. Housing 56 includes a sleeve portion 59 extending upwardly and slidably supported on a cylindrical stud-like guide member 61. Member 51 is fixed to bridge member 24 by a flanged portion 62 screwed to same. The end of member 61 is formed with an inverted conical surface 63 adapted to receive a generally similar surface at the upper end of member 51. Housing 56 is yieldingly urged to move member 51 to rotor engaging position by means of a helical spring 64 interposed between flange 26 and the upper surface of housing 56. The upper surface of housing 55 and under-surface of housing 56 are frictionally engaged after member 51 is received by sleeve 15. Suitable compressive force is thereby applied by spring 64 to provide damping as a function of the loading of the engaged surfaces of housings 55, 56.

A temperature transducer is carried by bearing assembly 50 to extend into sleeve 15 and is radiometrically coupled with the black body interior surface of the sleeve. Member 51 is disposed with respect to the temperature transducer to protect the latter from contact with sleeve 15 during lateral movement thereof, as during damping of the rotor. Thus, a thermistor bead 65 connected by suitable leads is mounted in a transducer holder 66 to extend coaxially through guide member 61 and member 51. Holder 66 rests on a shoulder formed in guide member 61. In order to promote efficient radiation coupling between thermistor 65 and the black body interior surface of the sleeve 15 and protect against radiation leakage, a cylindrically-shaped blackened guard ring 67 is fastened to the bottom of housing 56. A retaining ring 68 is interposed between ring 67 and housing 56 to retain housing 55. A radiation shield 69 of generally circular construction is carried by posts 71 depending downwardly from member 24. The lower surface of shield 69 is also blackened.

Means serving to move rotatable member 51 of bearing assembly 50 between advanced and retracted positions includes a pair of arms 72 each pivoted at 73 and being formed at their opposite ends with relatively large square holes 74 adapted to receive trunnions 75 carried on each side of housing 56. Trunnions 75 are, therefore, free to move laterally and vertically to a limited degree within holes 74. Furthermore, it should be noted that housing 56 is also free to rotate slightly by virtue of the limited clearance provided by holes 74. Arms 72 are yieldingly urged upwardly by a lift spring 76 disposed to extend between arms 72 and a member fixed with respect to bridge member 24. As shown spring 76 is in its extended position.

Means for moving arms 72 upwardly include a solenoid 77 provided with an armature 78 spring loaded to the right, as shown in the drawings. The end of armature 78 carries a transverse rod or clevis pin 79. The ends of clevis pin 79 are each coupled by links 81 to a pair of links 82, 83 whereby leftward movement of armature 78 serves to extend the over-all length of links 82, 83 to drive arms 72 downwardly to the position shown. Correspondingly, relaxation, or de-energization of solenoid 77 serves to spring urge armature 78 to the right thereby shortening the over-all length of links 82, 83 whereby arms 72 are raised. Thus, arms 72 and member 51 are movable between advanced and retracted positions depending upon energization of solenoid 77.

Electrical leads for solenoid 77 are brought out beneath member 24 and along one of the pivot arms 42 to a wiring connector plug 84 which in turn makes connection with electrical leads carried by frame 11.

Means serving to energize solenoid 77 below a predetermined speed of rotation and responsive to rotation of rotor 13 above the predetermined speed to move member 51 between advanced and retracted positions further includes the circuitry generally shown schematically in FIGURE 1. As there shown, a speed transducer 86 is disposed to detect the rotational speed of spindle 14. Transducer 86 feeds a signal to speed control circuit 87. Speed control

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circuit 87 includes a relay 88 connected to be energized whenever the speed of rotation of spindle 14 is above a predetermined velocity. Relay 88 is connected to operate the coil of solenoid 77 whereby energization of relay 88 serves to deenergize solenoid 77.

Suitable means for providing the foregoing function can include the speed control circuit of a model L-2 centrifuge apparatus as manufactured by Spinco Division of Beckman Instruments Corporation, Fullerton, Calif. A voltage generator responsive to rotational speed of spindle 14 can be suitably arranged whereby at a predetermined speed sufficient voltage is generated to energize relay 88 thereby opening the circuit of solenoid 77.

Operation of the foregoing apparatus is as follows:

With a selected rotor 13 mounted upon spindle 14 the stabilizing assembly is pivoted over opening 12 and moved vertically downwardly into chamber 17 to an appropriate level. At the selected level pins 29 are inserted into the corresponding detents and pin 30 is adjusted outwardly to engage a detent on bracket 19. Visual inspection of level 38 readily determines a correct mounting of the apparatus. Inasmuch as the rotor is not yet operating, solenoid 77 will be energized thereby moving arms 72 downwardly carrying rotatable member 51 to an advanced position. Member 51 is inserted into and engages sleeve 15 to hold same generally about its geometric axis of rotation. As the rotor is brought up to speed it will tend to rotate about its true center of gravity of the mass as distinguished from the geometric center of the rotor and will cause a lateral displacement of the rotor. Lateral displacement of the rotor is accommodated by well 57 and pin 58 and any wobbling of the rotor is damped by friction between the upper surface of housing 55 and under-surface of housing 56, as the rotating member 51 orbits about the true axis of rotation. During damping, member 51 will move in an orbit about the axis defined by the center of guide member 61. The radial limits for these revolutions will, of course, be defined by the clearance between the inner wall of housing 56 and the outer wall of housing 55. Well 57 and pin 58 prevent housing 55 from spinning with respect to housing 56. After rotor 13 has passed its critical speed and has begun to rotate steadily about an axis through its own center of gravity, relay 88 is energized thereby deenergizing solenoid 77. As solenoid 77 is de-energized the spring load therein moves armature 78 to the right and, with the aid of spring 76, raises arms 72 upwardly to retract member 51. The same retraction is effected, it shall be noted, should there be a power failure to solenoid 77. Accordingly, the possibility that rotor 13 could be operated at its ultra-high speeds in contact with member 51 is precluded. During upward movement of member 51, surface 63 serves to coaxially align member 51 generally with the axis of rotation of rotor 13 so that prior to movement of member 51 downwardly into engagement with sleeve 15 it will be substantially properly centered.

After a centrifuging operation is completed rotor 13 commences to slow down. As it passes a transition speed of rotation wherein wobbling might be expected (as is shown), solenoid 77 is again energized and armature 78 moved leftwardly to extend the over-all length of links 82, 83 to carry arms 72 downwardly driving housing 56 and member 51 into engagement with sleeve 15. Engagement between member 51 and sleeve 15 serves to damp wobbling of the rotor 13 and thereby prevent re-mixing of the centrifugate separated by the centrifuging operation.

From the foregoing it will be readily evident that there is provided a novel stabilizing apparatus whereby the rotor is not only stabilized but is damped as well. It should be further observed that a radiation coupled temperature transducer is fully protected by the same rotatable member which serves to provide stabilization and damping.

We claim:

1. An apparatus, including a bearing assembly, for

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stabilizing a centrifuge rotor about its true axis of rotation through low speeds and for damping lateral movement of the rotor with respect to a supporting frame, said apparatus comprising

- 5 a member, rotatably mounted in said bearing assembly, for engaging said rotor whereby said rotor is held for rotation about said true axis of rotation, said member having an axis substantially coincident with said true axis of rotation;
- 10 means mounted in said bearing assembly for carrying said member, said carrying means being movable with yielding resistance within predetermined limits laterally of said axis of rotation whereby said axis of said member is movable in an orbit about said true axis of rotation and whereby said lateral movement of said rotor is damped;
- 15 means connected to said member and being responsive to the transition of said rotor from one speed range to another for moving said member between a rotor-engaging position and a rotor-releasing position.
2. An apparatus as defined in claim 1 in which said member extends downwardly from said bearing assembly; and
- 20 an upwardly extending sleeve is mounted on said rotor and coaxially thereof for frictionally receiving said member.
3. An apparatus as defined in claim 2 in which said sleeve has an inner, blackened surface; and a temperature transducer, extending downwardly into
- 30 said sleeve, is carried by said bearing assembly.
4. An apparatus as defined in claim 1 which includes means for substantially aligning said axis of said member with said axis of rotation prior to engagement of said rotor by said member.
- 35 5. An apparatus for stabilizing a centrifuge rotor about a true axis of rotation during operation within a predetermined speed range, said rotor being mounted for rotation in a housing, said apparatus comprising
- 40 an upwardly extending cylindrical sleeve mounted on said rotor, said sleeve being disposed coaxially of said rotor and having an inner blackened surface;
- 45 a bearing assembly supported by said housing;
- a member, rotatably mounted in said bearing assembly, for engaging said sleeve whereby said rotor is held for rotation about said true axis of rotation, said member having an axis substantially coincident with said true axis of rotation;
- 50 means responsive to rotor speed and connected to said member, for moving said member into engagement with said sleeve when said rotor speed enters said predetermined speed range and out of engagement with said sleeve when said rotor speed leaves said predetermined speed range;
- 55 a temperature transducer disposed substantially centrally inside said sleeve, said transducer being smaller than the inside diameter of said sleeve; and
- a temperature transducer holder connected to said bearing assembly, said temperature transducer being attached to said holder, said member being disposed about said holder whereby said temperature transducer is protected from contact with said sleeve.
6. An apparatus as defined in claim 5 in which said means for moving said member into and out of engagement with said rotor sleeve includes a spring-loaded solenoid actuator having an armature connected to said member whereby said member is moved into said engagement when said solenoid actuator is energized and out of engagement when said solenoid actuator is de-energized.
7. An apparatus for stabilizing a centrifuge rotor, with respect to a frame supporting said rotor, about the axis of rotation of said rotor through low speed ranges, said stabilizing apparatus comprising
- 70 a bearing assembly carried by said frame;
- a bearing mounted in said bearing assembly;
- 75 means for engaging said rotor to hold said rotor during

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rotation, said rotor-engaging means being supported by said bearing and rotatable substantially about said axis of rotation of said rotor, said rotor-engaging means being laterally movable with yielding resistance within predetermined limits;

means connected to said rotor-engaging means for moving said rotor-engaging means between rotor-engaging and rotor-releasing positions;

means connected to said rotor-engaging means for yieldingly urging said rotor-engaging means to said rotor-engaging position; and

means connected to said rotor-engaging means responsive to rotation of said rotor above a predetermined speed for moving said rotor-engaging means toward said rotor-releasing position.

8. An apparatus as defined in claim 7 in which said rotation-responsive means includes a solenoid actuator having an armature connected to said rotor-engaging means whereby said rotor is engaged when said solenoid actuator is energized.

9. An apparatus for stabilizing a centrifuge rotor about an axis of rotation extending through the center of gravity of the combined mass of the rotor and the contents thereof during low speeds and for damping lateral movement of the rotor with respect to a rotor-supporting frame, said apparatus comprising

a bearing assembly carried by said frame;

a rotor-engaging member for stabilizing rotation of said rotor about said axis of rotation, said member being rotatably mounted on said bearing assembly substantially coaxially of said axis of rotation;

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means connected to said member for moving said member between first and second positions to engage and release said rotor, said means being responsive to transition of said rotor from one speed range to another;

damping means mounted in said bearing assembly for carrying said member and restricting lateral movement of said member within predetermined limits of said axis of rotation, said damping means including a pair of elements having substantially coplanar surfaces, said pair of elements moving relative to each other during lateral movement of said rotor with respect to said axis of rotation; and

means connected to one of said elements for yieldingly urging said surfaces into frictional engagement whereby said lateral movement of said rotor is damped.

References Cited

UNITED STATES PATENTS

1,955,746	4/1934	Inglis	74—5.1 X
1,968,692	7/1934	Krauss	210—144
2,878,992	3/1954	Pickels et al.	233—26
2,885,188	5/1959	Pickels et al.	233—11 X
3,246,688	4/1966	Colburn	233—11 X

FOREIGN PATENTS

148,309	6/1921	Great Britain.
777,973	7/1957	Great Britain.

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