Nov. 1, 1966 L. B. SMITH 3,282,498

CONSTRUCTION FOR HIGH GRAVITY CENTRIFUGES AND THE LIKE

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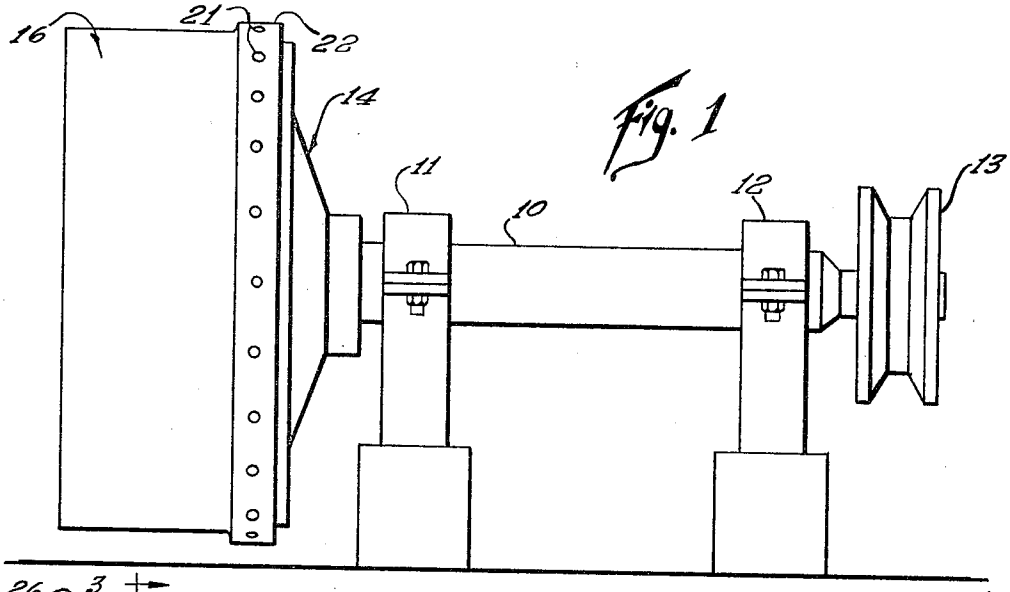


Fig. 1

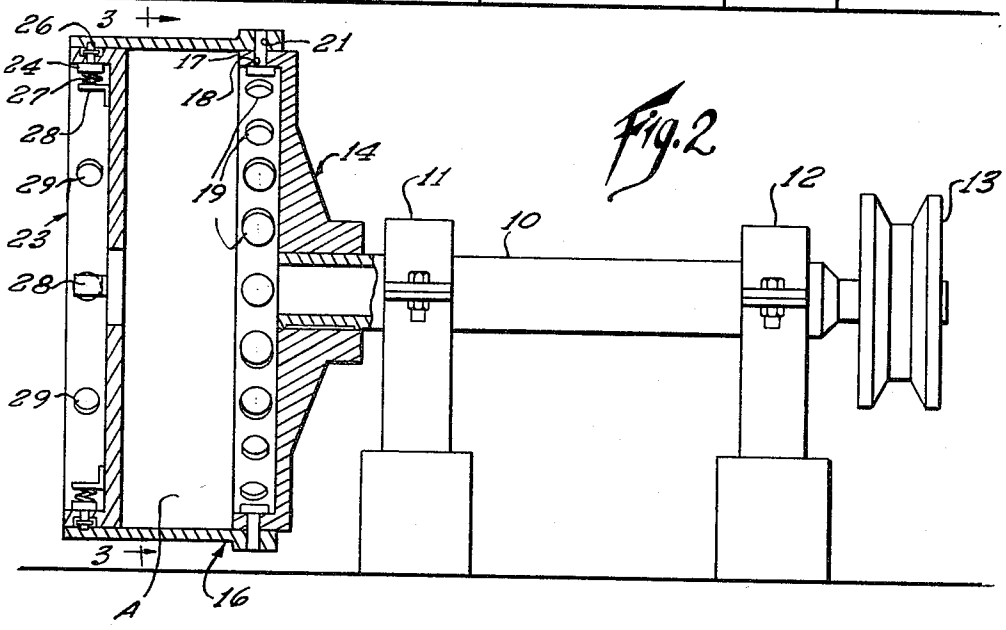


Fig. 2

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Fig. 3

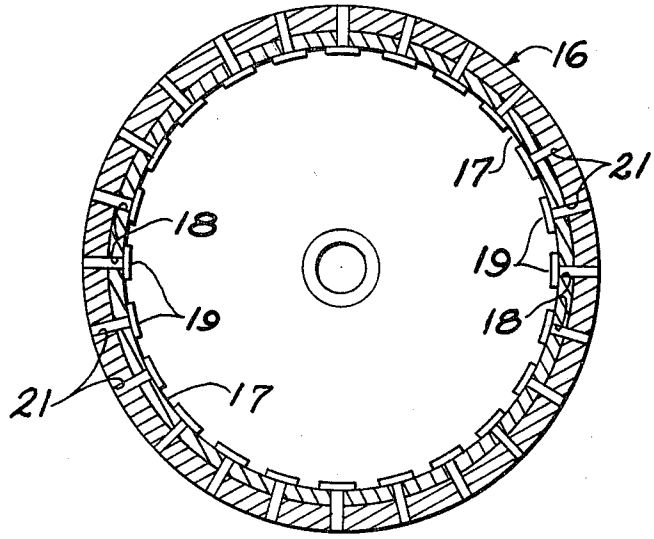
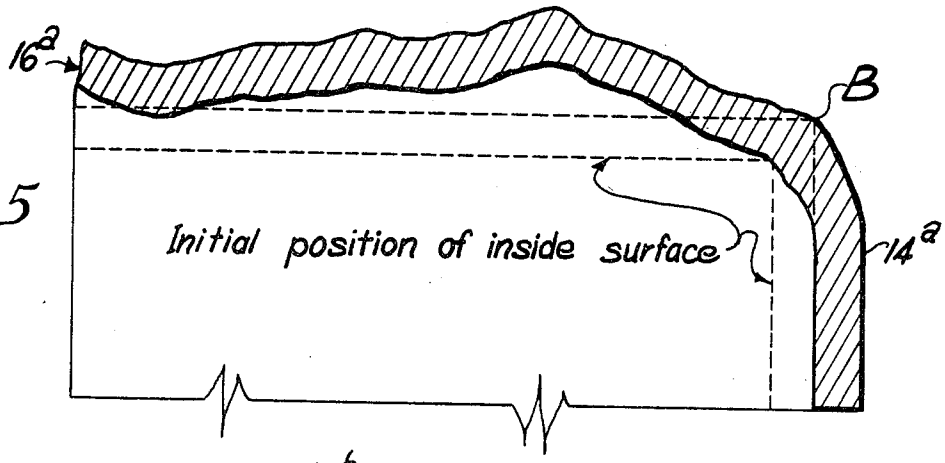


Fig. 5



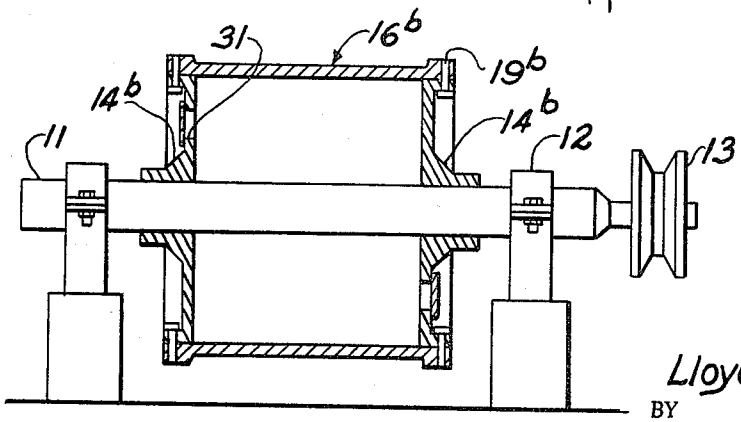


Fig. 4

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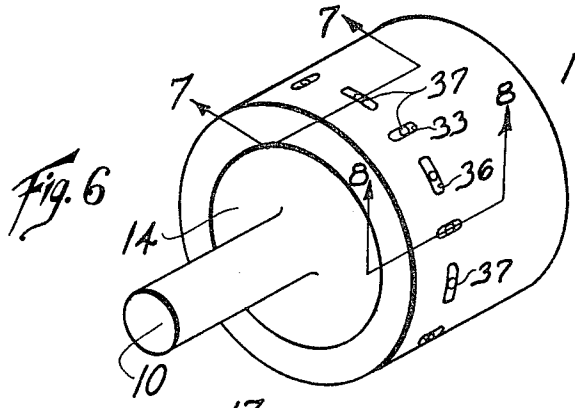


Fig. 6

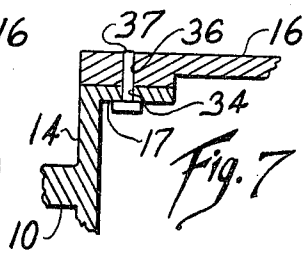


Fig. 7

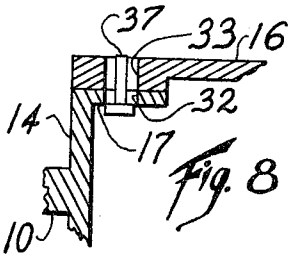


Fig. 8

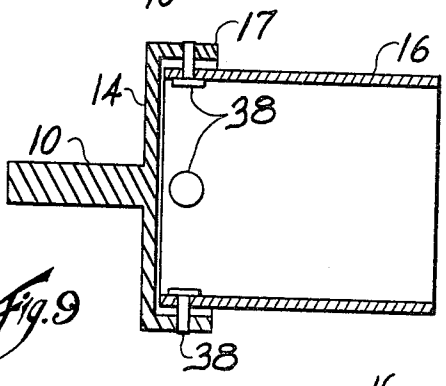


Fig. 9

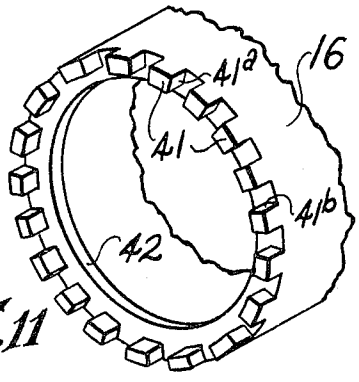


Fig. 11

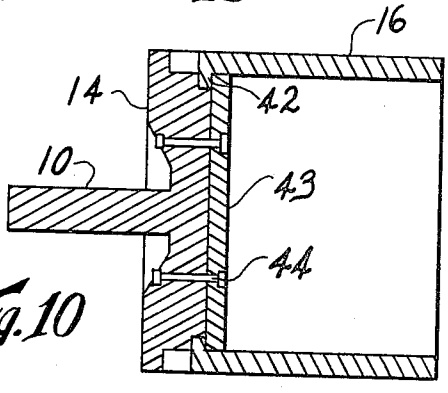


Fig. 10

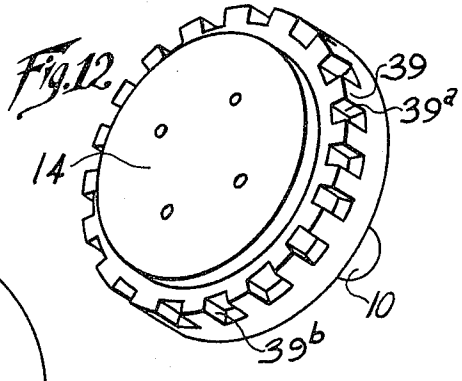


Fig. 12

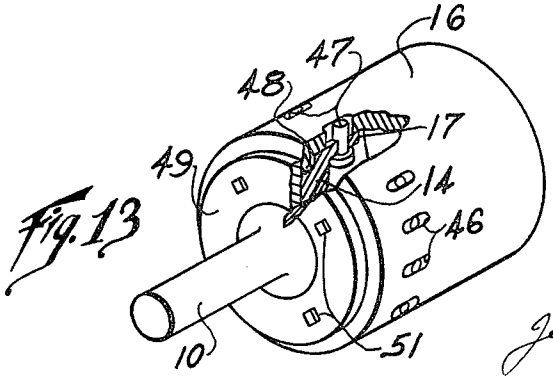


Fig. 13

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3,282,498

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3,282,498

CONSTRUCTION FOR HIGH GRAVITY CENTRIFUGES AND THE LIKE

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Filed June 10, 1963, Ser. No. 286,849

7 Claims. (Cl. 233—27)

This application is a continuation-in-part of my co-pending application Serial No. 69,649 filed Nov. 16, 1960, "Construction for High Gravity Centrifuges and the Like," now bandoned.

This invention relates to an improved construction for high gravity centrifuges and the like and its principal object is to provide a construction which shall permit the centrifuge to turn at higher speeds than heretofore obtainable without overstressing the shell thereof.

In the art to which this invention relates, the problems of metal stress on peripheral portions of high gravity centrifuges and like apparatus have not, so far as I know, been fully solved. That is, in prior constructions, the cylindrical or shell portion of such apparatus has either been cast integrally with the radial portion, or if made separately therefrom, has been bolted, riveted, welded or otherwise mechanically secured thereto. With such prior constructions there is overstressing of the metal, if formed integrally, or overstressing of the fastening means if formed separately, at relatively slow rotational speeds of the apparatus. The maximum centrifugal force which can be developed by such prior apparatus, therefore, has been comparatively small inasmuch as such constructions have necessitated operation at relatively low speeds to prevent eventual disintegration of the structure.

In my investigations into this subject I now believe that the theoretically perfect type of centrifuge is one in which the cylindrical portion or shell is free to act, when rotating, as does a free hoop. That is, the ideal stress-strain relationship on the shell occurs when the shell is permitted to enlarge, "grow," or stretch precisely in the unrestricted or unconfined manner of a freely rotating hoop or cylinder. At the same time, the means connecting the shell to the driven radial part of the structure must be effective to hold the axes of the shell and radial part in alignment; otherwise the entire apparatus will become dynamically unbalanced. Further, with centrifuges of the size contemplated by my invention, namely those capable of producing bales of fibers on the order of 500 pounds, the connecting means must be rugged enough to transmit the driving forces while permitting the shell to "grow."

In view of the foregoing, the prime object of my invention is to overcome the aforementioned difficulties in prior centrifuge constructions.

My invention is characterized in one aspect by the provision of means to support the centrifuge shell in a manner fully adequate to transmit rotational forces thereto, while at the same time permitting the shell to "grow," or increase in diameter under the influence of centrifugal force without overstressing the shell in any local areas over its surface.

My invention is characterized in another aspect by the provision of such "growth" permitting means which, either of itself or by the addition of other connecting means assures the maintenance of axial alignment of the shell and the associated driven axial part or head of the centrifuge.

More particularly, this invention contemplates a centrifuge in which the radial shaft supported head or heads is or are, as the case may be, separately formed from the shell. The shell is supported from the periphery of the head or heads by means of a plurality of pins or equivalent members which may be carried by the head

or heads, and passing into or through the shell. The pins or other projections employed extend along the natural paths of expansion or "growth" of the shell. Since the shell thus is free to slide along the pins, no restraint to radial "growth" or expansion is imposed on the shell. As a consequence of this construction the shell is equally stressed throughout its entire area when rotating, and the metal thereof is in true tension. At the same time the shell is held in axial alignment with the radial part. Therefore, unlike prior apparatus, the possible, practical speed of rotation of my improved apparatus, insofar as shell stresses and balancing are concerned, is limited only by bearing requirements and the tensile strength of the metal from which the shell is constructed. I thus provide a construction which makes possible very large size apparatus such as centrifuges, thereby to accommodate large amounts of material which can safely be subjected to a tremendously high number of gravities. As this description proceeds it will become apparent that the principles of construction of my invention are applicable also to small diameter centrifuges and other apparatus, permitting higher speeds and the attendant higher gravities than are obtainable with prior constructions. Further, my invention conceivably has utility in connection with the construction of various other types of apparatus in which it is desired to rotate a cylinder or shell, at extremely high speeds, about its own axis.

Apparatus illustrating features of my invention is shown in the accompanying drawings forming a part of this application, in which:

FIG. 1 is a side elevational view of a centrifuge embodying my improved construction;

FIG. 2 is a side elevational view corresponding to FIG. 1 with parts of the apparatus broken away and in section;

FIG. 3 is a detail sectional view taken generally along line 3—3 of FIG. 2;

FIG. 4 is a vertical sectional view of a modified form of my invention;

FIG. 5 is a diagrammatic illustration of the distortion of a prior art centrifuge under high speed conditions, the scale of the view being greatly magnified in the vertical direction;

FIG. 6 is a somewhat diagrammatic isometric view of a modified form of my invention;

FIG. 7 is a detail sectional view taken generally along the line 7—7 of FIG. 6;

FIG. 8 is a detail sectional view taken generally along line 8—8 of FIG. 6;

FIG. 9 is a somewhat diagrammatic cross sectional view showing a further modified form of my invention;

FIG. 10 is a vertical sectional view showing still another form of my invention;

FIG. 11 is an isometric, fragmental view of the splined and flanged end of the shell of the centrifuge shown in FIG. 10;

FIG. 12 is an isometric view of the splined radial member of the centrifuge shown in FIG. 10; and

FIG. 13 is a somewhat diagrammatic isometric view, partly in section, of yet another modification of my invention.

Referring now to the drawings for a better understanding of my invention and more particularly to FIGS. 1 to 3 inclusive, I illustrate my invention in association with a centrifuge embodying a shaft **10**. The shaft **10** may be supported for rotation in suitable bearings **11** and **12** and power for rotating the shaft may be supplied through a pulley **13**.

The centrifuge proper comprises a radial part or head indicated generally at **14** and the shell or cylindrical portion indicated generally by the numeral **16**. The radial portion **14** is mounted non-rotatably on the shaft **10**.

The shell and radial portion form a material receiving chamber A in which a bale of fibers may be formed as taught in my co-pending application Serial No. 33,301, "Process and Apparatus for Baling Fibers and Bale Formed Thereby," filed June 1, 1960, now Patent No. 3,133,563.

The periphery of the radial portion may be turned inwardly as indicated thus to provide a shoulder **17**. In the shoulder are a plurality of openings **18** which are spaced equiangularly about the periphery of the head. Further, it will be noted that the openings extend radially from the central axis of the head.

Secured in the openings **18**, as by a press fit, are headed pins **19**. It will be noted that the heads rest on the shoulder **17**. The pins pass snugly but slidably through openings **21** provided about the periphery of the shell **16**. Also, the shell **16** may be thickened at the point where the holes **21** are provided by an annular strengthening band **22**.

If desired, the centrifuge may be provided with a removable closure member indicated generally by the numeral **23**. This member may be held in place by means of a plurality of pins **24** which have reduced ends fitting in an annular groove **26** formed in the inner surface of the shell **16**. The pins may be biased inwardly by means of springs **27** which rest on plates **28**. Other headed pins **29** may be provided to fit also in the groove **26**. The pins **29** do not necessarily have to have the springs **27**, inasmuch as when the centrifuge is started, centrifugal force will urge them outwardly.

Considering now the action that takes place upon rotation of a centrifuge constructed as just described, it will first be seen that all the rotational forces are imparted to the shell **16** through the pins **19**. Since the pins **19** are radially disposed, they thus provide a plurality of "paths of growth" for the shell **16** when the same tends to "grow" or expand in diameter as the centrifuge is rotated. Therefore, even though the centrifuge may increase in diameter by as much as 15 or 20 thousandths of an inch, the shell **16** proper, under those conditions, is free to expand without any bending or other stress of the metal at the point of juncture of the shell with the radial part **14**. The shell thus behaves precisely as does a freely spinning hoop or cylinder. Further, since the pins fit snugly in the openings **21**, even when the shell increases in diameter the pins effectively hold the axes of the shell and radial head in alignment. The pin construction thus serves the three essential functions of driving the shell, permitting it to expand, and holding it centered.

Referring particularly to FIG. 5 of the drawings, I have there illustrated an exact example of what takes place in a high gravity centrifuge, made according to the prior art. In this case it will be understood that the radial portion **14a** and the shell portion **16a** were cast or made integrally. The dotted lines in FIG. 5 represent the initial position of the respective parts at rest. It is to be pointed out that FIG. 5 represents a test on a centrifuge having a cylinder of 5.1 inches inside diameter and 2 inches long. The steel from which this shell was made was tested and yielded at 39,000 pounds per square inch in a tensile test machine.

Upon turning the centrifuge of FIG. 5 at 15,000 r.p.m. there were developed 33,100 gravities at the rim, namely, at the outer surface of the shell part **16a**. At 24,000 r.p.m. the shell and head of FIG. 5 took the configuration indicated by the full lines. It will be understood that the vertical dimension of FIG. 5 is exaggerated 500 times the axial dimension. However, it will be noted at the point of juncture of the head **14a** and shell **16a** indicated by the letter B there has been an undue bending and a complete overstressing of the metal. It is further to be noted that the peculiar dislocation of the shell along the axis from the head **14a** was present and that this distortion itself is serious. It will further be noted that the original square corner at the point of juncture B has been rounded off, showing the tremendous stress at that point.

While the deformation indicated in FIG. 5 occurred at 24,000 r.p.m., measurements showed that the failure started at between 15,000 and 20,000 r.p.m.

I next constructed a centrifuge of the same size, formed of the same metal, and made substantially in accordance with FIGS. 1 to 3, above described. In view of the fact that the calculations for the particular steel from which the shell was made indicated that it would yield at 26,110 r.p.m., I stopped the test at that point as indicated below:

Centrifuge made according to FIGS. 1 TO 3 inclusive

15,000 r.p.m.=33,100 gravities at rim
20,000 r.p.m.=58,900 gravities at rim
24,000 r.p.m.=84,500 gravities at rim
26,100 r.p.m.=99,800 gravities at rim

It will be understood that with both of these models they were made of highly polished steel and that after the runs they were carefully measured. The deformation shown in FIG. 5 actually took place in the model made according to the prior art, whereas after running the improved centrifuge up to 26,100 r.p.m., I could note no permanent deformation of the shell portion. Further, no unbalance of the apparatus was noted and since at the speeds indicated had there been any appreciable unbalance due to axial misalignment of the shell relative to the head, the apparatus undoubtedly would have destroyed itself. Thus, it will be seen that while the prior art centrifuge tested did not disintegrate during the one test, it is apparent that with repeated uses it undoubtedly would fail, probably first at the point of juncture B. On the other hand, with my improved construction so long as the elastic limit of the steel from which the shell is made is not exceeded, a device capable of long life and high gravities is provided.

In FIG. 4 of the drawings, I show my invention as applied to a centrifuge having two heads supporting the shell. Thus, the heads **14b** carry the pins **19b**, laid out around the periphery of the heads as already has been described. These pass through the aligned holes in the shell **16b**. If desired, material may be introduced into or removed from the chamber B of the centrifuge of FIG. 4 through openings **31** in the heads. It will be noted, of course, that the bearings **11** and **12** are at either end of the centrifuge rather than having the same overhang the bearings **11** in a cantilever fashion as in FIGS. 1, 2 and 3.

With respect to FIG. 4 it will be seen that the advantages relative to preventing overstressing of the apparatus at the point of connection of the shell with the heads while holding the shell centered are equally present.

In FIGS. 6 to 13, I show additional and modified forms of my invention. In all of these modifications, as the description proceeds, it will be seen that means is provided for permitting the shell to grow in unrestrained or unrestricted manner, while at the same time such connecting means transmits the rotational force of the driven head or radial part to the shell, and either this same means, or additional means, holds the rotational axis of the shell in alignment with the rotational axis of the head or radial part.

Referring particularly to FIGS. 6 to 8 inclusive, the head or radial part **14** carried by the shaft **10** may be provided with a series of elongated openings or slots **32** which are generally parallel to the longitudinal axis of the shell. In alignment with these slots **32** are similarly elongated slots **33** in the shell **16** (see FIG. 8). Between the slots **32–33** are other slots in the flange of the head **14** indicated at **34**, these slots extending normal to the longitudinal axis of the centrifuge shell. In similar manner, the shell is provided with cooperating slots **36**. Passing through the slots are headed pins **37**.

From what has just been described it will be seen that the pins **37** in the slots **32–33** serve the purpose of transmitting rotational force to the shell from the driven head and keep the axis of the shell coincident with the axis of

the head. The pins **37** in the slots **34–36** serve the purpose of preventing the longitudinal or rotational axis of the shell from getting out of parallel alignment with the rotational axis of the head. All of the pins **37** simply project through the respective slots in the shell, fitting snugly therein so that as the shell grows or expands the pins provide surfaces on which the shell may slide, thereby to permit such growth. It will be understood, of course, that the pins **37** all are laid out radially, thus to lie along the natural paths of diametric expansion or growth of the shell.

In FIG. 9 I show a modification in which the head **14**, provided with the shoulder **17**, surrounds the shell **16** rather than having the shell **16** surround the shoulder or flange **17**. In this instance the shell **16** is made slightly smaller in diameter, this difference being exaggerated in the drawings for the sake of clarity. The shell is sized so that the outer circumference thereof never touches the inner circumference of the shoulder **17**, when the centrifuge is operated at its maximum speed. The pins **38** have their heads resting against the inner surface of the shell and are laid out radially as stated.

In FIGS. 10 to 12, I show still another form of my invention. In this instance the head **14** is provided with a plurality of splines **39**, the opposite sides **39a** and **39b** of which are radially disposed. Disposed to fit in these splines are cooperating splines **41** on the end of the shell, the surfaces **41a** and **41b** of which are similarly radially disposed. The function of the splines is to transmit the rotational force of the head to the shell **16** and to hold the rotational axes of the shell and head coincident.

The shell is provided with an inturned circummferential flange **42**. This flange is engaged by means of a plate **43** secured to the head **16** by a number of nuts and bolts **44** as shown. Thus, when the centrifuge of FIGS. 10 to 12 is operating at full speed the shell is free to grow, in unrestrained manner, it being understood that the surfaces of the splines, being radially cut, permit free outward growth of the shell. At the same time, shoulder **42** is free to slidably expand relative to the plate **43** and the adjacent portion of the head, while maintaining parallel alignment of the rotational axes of the head and shell.

In FIG. 13, I show the shell **16** as provided with a plurality of slots **46** which are elongated axially. The inturned flange **17** of the head **14** is provided with openings to receive a plurality of pins **47** which project into the slots **46**. The shell is provided with an inturned circumferential flange **48** which fits on the outside of the head **14**. A plate **49** engages the outer side of the flange **48** and holds it slidably in contact with the head **14**, a plurality of studs or the like **51** being used to secure the plate **49** in place. Again the pins **47** transmit the driving force and hold the axes coincident, while the flange **48** and plate **49** hold the axes parallel.

In view of the foregoing, it will be apparent that I have invented an improved construction for centrifuges which makes possible the construction of both large and small diameter centrifuges and other similar apparatus which can be operated at speeds heretofore not obtainable. By permitting the shell to expand or "grow" along its natural lines of expansion when under centrifugal force, and simultaneously transmitting the rotational force to the shell along or through these same "paths of growth" while maintaining the axis of the shell centered and aligned relative to the head, I obtain a centrifuge in which the shell truly acts as if it were turning freely, without any connection to the head insofar as freedom to expand radially is concerned. At the same time, I have eliminated the unbalancing problems which would occur if the shell became out of alignment with the head, whereupon it would tend to "wobble" or turn around an elliptical path, at least on its outer or free end, thus assuring that the apparatus remains in balance. While I have shown all of the embodiments of my invention as being mounted for rotation about a horizontal axis, it will be understood that it is possible, if desired, to mount the apparatus upon a vertical shaft.

My improved construction is particularly adaptable for use in large diameter centrifuges for such processes as the baling of fibers and the separation of other materials which lend themselves to centrifugation. It will be understood that even in a large centrifuge of say 52 inches internal diameter, the "growth" spoken of herein, at speeds of say 2400 r.p.m. may not exceed .025 thousandth inch. However, by eliminating the bending at the point of connection of the shell with the head, I completely relieve the fatiguing and overstressing of the metal at such point or points.

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are specifically set forth in the appended claims.

What I claim is:

1. In a high gravity centrifuge having a cylindrical shell-like part open at both ends and subject to increase in diameter in response to centrifugal force and a radial driven part concentric with the shell-like part, the improvement comprising a plurality of elongated members radially disposed relative to the periphery of the radial part, and means fixedly securing said members to one of said parts for sliding movement relative to the other thereof, whereby rotational force is transmitted between the inner part and the outer part through said members while permitting unrestrained increase in diameter of the shell-like part when subjected to centrifugal force, and means to hold the rotational axes of the shell-like and radical parts in alignment while the shell-like part increases in diameter.

2. In centrifuge-like apparatus, an outer cylinder-like shell, a radial driven part having its rotational axis aligned with the rotational axis of the shell, a plurality of members connecting the shell adjacent one end to the driven part and having sliding surfaces lying along paths of natural expansion of the shell when the shell is under centrifugal force, and means mounting said plurality of members for transmission of said rotational force while offering substantially no resistance to said expansion of the shell.

3. Apparatus defined in claim **2** in which said plurality of members is in the form of pins secured to the radial part and projecting into sliding rotational force transmitting contact through the shell.

4. In a high gravity centrifuge, an outer cylindrical shell open at both ends, a radial driven part having its rotational axis aligned with the longitudinal axis of the shell, a plurality of pins fixedly mounted on the periphery of the radial part and projecting outwardly therefrom through the shell and into axial sliding engagement with the shell, the longitudinal axes of said pins lying along lines of natural diametric expansion of the shell when the shell is under centrifugal force, and means to hold said axis aligned as the shell expands under the influence of centrifugal force.

5. In a high gravity centrifuge, a radially disposed part driven from its center, a cylindrical shell open at both ends and having one end fitting over the periphery of the radial part and having its longitudinal axis aligned with the rotational axis of the radial part, and a plurality of pins passing snugly but slidably through the shell and secured against outward axial movement relative to the radially disposed part, said pins having their longitudinal axes disposed radially of the centrifuge, whereby the shell may expand or "grow" in diameter in response to centrifugal force thereon, and said pins being constructed and arranged to hold the axes of the shell and radial part in alignment as the shell expands when subjected to centrifugal force.

6. In a high gravity centrifuge, a driven shaft, a radial head portion carried by the shaft, a cylindrical shell open at both ends and disposed for connection adjacent one end with the periphery of the radial part, a plurality of members having radially disposed surfaces connecting the head to the shell and affording a plurality of non-rigidly connected driving means between the head and shell whereby the shell may freely expand away from the head in response to the diameter increasing effect on the shell of centrifugal force, and other radially disposed surfaces interconnecting the shell and head and effective to maintain the rotational axes of the shell and head in alignment while the said shell expands.

7. Apparatus as defined in claim 6 in which the members connecting the head and shell are in the form of a plurality of radially disposed pins which provide both sets of said radially disposed surfaces functioning as stated.

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