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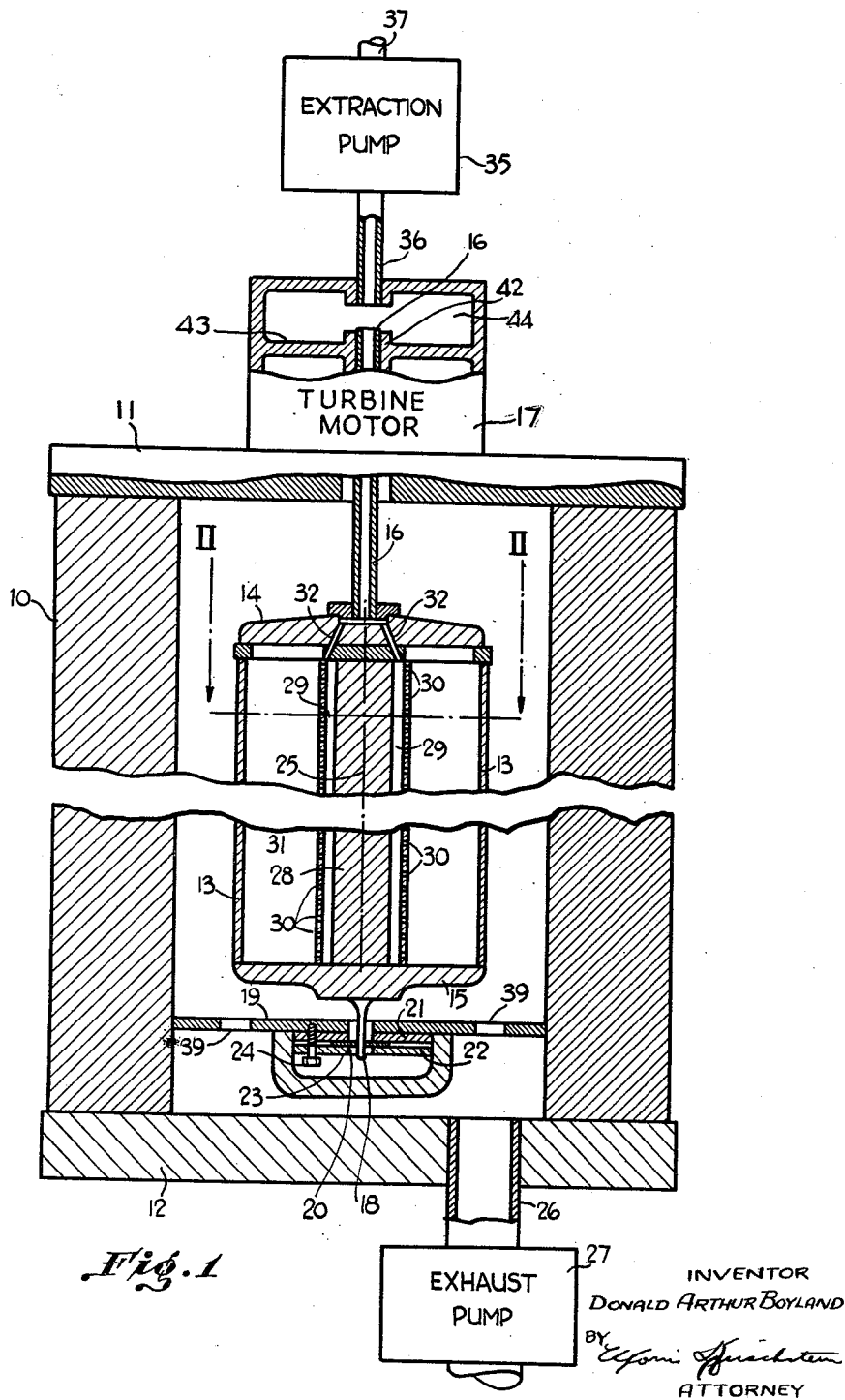
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HOLLOW ROTORS AND CENTRIFUGES

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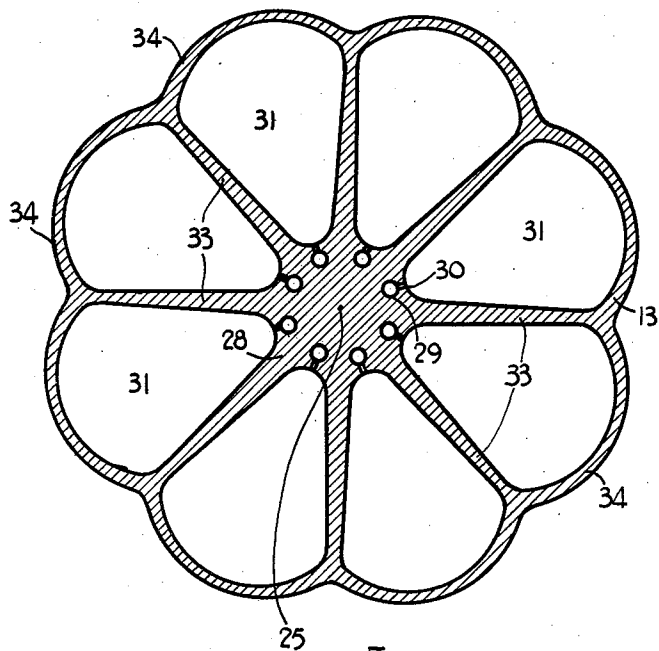


FIG. 2.

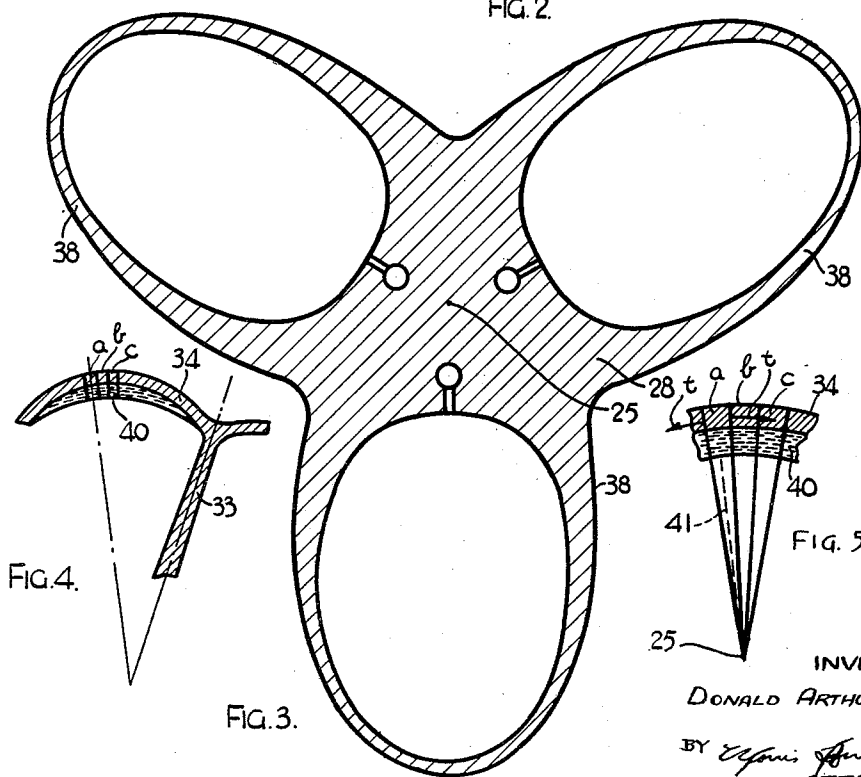


FIG. 4.

FIG. 3.

FIG. 5.

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HOLLOW ROTORS AND CENTRIFUGES

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This invention relates to centrifuges and rotary hollow bodies for operation at high peripheral velocities necessitating design specifically to withstand the stresses due to centrifugal force.

The invention is applicable for example to the improvement of continuous-flow vacuum-type tubular centrifuges as disclosed in the paper by J. W. Beams in Review of Scientific Instruments at page 413 of volume 9, 1938, and to so-called evaporative centrifuges arranged so that vapour may be withdrawn from near the axis of a hollow spinning rotor containing liquid near its periphery as disclosed in the paper by J. W. Beams in the Physical Review at page 266 of volume 56, 1939. The efficiency of such centrifuges in the separation of gases is dependent on the speed of rotation which is in practice limited by the resistance of the material of the rotor to the stresses due to centrifugal force. Reinforcement of the rotors in such centrifuges, for example by spokes of webs, has in the past led to but small improvement in the limiting speed and has introduced complication in the stress distribution such that the strength of the rotor was in doubt.

The present invention has for an object to provide improved constructions or shapes of rotor for high-speed operation and to this end resides in arranging the rotor cross-section transverse to the axis of rotation as a series of loops each extending from a central boss, the portions of adjacent loops extending from the boss to a radius less than the excursion of the loops being common or interconnected.

Another aspect of the invention arises from a consideration of the known rotor comprising a long circular cylinder, end-supported, wherein centrifugal force sets up a circumferential tensile stress in the cylinder. In a rotor comprising a circular cylinder supported on radial webs, there is set up, in addition to the circumferential stress in the cylinder, a radial stress in the webs and a bending moment in each span of the cylinder between the webs.

In the rotor of the invention, radial webs carry spans together forming a closed continuous wall encircling the webs, said spans being curved to lie outside the circular cylinder bounding the webs so that the bending moment is less than if the spans conformed to that circular cylinder. Preferably the spans are curved to conform as closely as possible to the line of resultant stress along them so that the bending moment becomes small or negligible. The stress at each point throughout the major part of the rotor is then such that two of the principal stresses are small in comparison with the third; each span is in fact of the shape which a span of similar dimensions and density but of flexible material would assume when rotating.

The rotor may be designed for uniform tensile stress throughout the material. The radial webs then become of thickness decreasing from a central boss to take as a simple radial stress the whole radial load applied to the ends of the webs; the spans or curved cylinder wall sections become of thickness decreasing with distance from the points of suspension on the webs.

The invention will be described, by way of example, with reference to the accompanying somewhat diagrammatic drawings in which

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FIG. 1 shows in part axial cross-section a centrifuge according to the invention,

FIG. 2 shows an enlarged view, in section on the line II-II of FIG. 1, of the rotor of FIG. 1,

FIG. 3 is a view similar to that of FIG. 2 of a modified form of rotor according to the invention, and

FIGS. 4 and 5 are diagrams of fragments of the rotor of FIG. 2 to illustrate the manner in which the rotor can be designed.

Referring to FIGS. 1 and 2, a centrifuge comprises a fixed outer casing consisting of a cylindrical body 10 and two end plates 11 and 12. Within the casing is rotatably mounted a rotor, of length substantially greater than its diameter, comprising a shell 13, having the contour shown in FIG. 2 having its ends closed by end plates 14 and 15. The rotor is suspended by a hollow spindle 16 which passes through suitable glands (not shown) to a driving motor 17 which may for example be of the turbine type.

The plate 15 at the lower end of the rotor carries a pin 18 passing through a clearance hole in a plate 19 fixed within the body 10 and into a Phosphor-bronze damping plate 20 in which it is a running fit. The plate 20 is located between two plates 21 and 22 and pressure is exerted between these plates by a spring 23, the pressure upon the plate 20 being adjustable by bolts 24. Thus while the lower end of the rotor is free to move slightly transversely with respect to its axis of rotation 25 such movement is damped by the action of the plates 20, 21 and 22.

The space between the rotor and the casing or body 10 can be evacuated through a pipe 26 in the lower plate 12 connecting with an exhaust pump 27, apertures 39 in the plate 19 connect the main space within the casing or body 10 with the pipe 26.

The rotor has a hub portion 28 having therein longitudinal exhaust passages 29 connected by apertures 30 with the interior 31 of the rotor and by passages 32 with the hollow spindle 16.

As seen in FIG. 2, the cross-section of the rotor comprises a plurality of webs 33 uniting the boss 28 with the shell 13. The latter comprises a number of spans 34 spanning the webs 33 and curved to a mean radius of the order of one quarter of the mean radius of the shell 13 as a whole. Thus the webs 33 and spans 34 form a plurality of loops extending radially from the boss 28. The curvature of the spans 34 and the thickness of the webs and spans are calculated for uniform tensile stress and zero bending moment. Thus the cross section of the webs 33 may decrease from the boss 28 outwards and that of the spans may decrease from their junction with the webs towards their centres.

In operation, fluid may be introduced through the tube 16, passages 32 and 29 and apertures 30 into the spaces 31 within the loops of the rotor. The rotor is driven by the turbine 17 at a suitably high speed and the lighter fraction which tends to collect near the axis can then be withdrawn by an extraction pump 35 which is connected with the interior of the hollow spindle 16 by a fixed pipe 36. This lighter fraction then appears at the outlet pipe 37. For the purpose of providing a connection between pipe 36 and the hollow spindle 16, the upper end of spindle 16 is carried by a bearing 42 in a diaphragm 43 across the upper part of the casing of the turbine 17, to which pipe 36 is connected, so that the said lighter fraction emerging from spindle 16 flows into the chamber 44 above diaphragm 43 from which it flows into pipe 36.

In FIG. 3 is shown, in cross-section, a rotor which may be used in place of that of FIG. 2 in the centrifuge of FIG. 1. This comprises three loops 38 extending radial-

ly from the boss 28, the curvature and thickness of the loops being designed for uniform tensile stress and zero bending moment. As in FIG. 2, longitudinal extraction passages 29 are provided in the boss 28 connecting with the interior of the loops 33 by apertures 30.

In known centrifuges for example of the kind described in the Physical Review paper above-mentioned, a limit is set to the peripheral speed by the tensile strength of the rotor. For normal steels this limit is of the order of 2.5×10^4 cms. per second. Such a tube may be strengthened by radial webs or spokes or by transverse discs but thickening of the cylinder at the junctions of the webs or discs is necessary to distribute the load without introducing large bending stresses. Consequently the radial stresses are considerably increased, the improvement in limiting peripheral speed is small and also the working volume inside the cylinder is reduced. The present invention, when applied as described to such a centrifuge, permits a greater peripheral speed and provides a greater working volume for given rotor dimensions.

The webs or loops of the rotor of FIGS. 2 and 3 have the further function of partitions preventing stirring of vapour in the rotor. The reduction of such stirring effects results in an improved separation efficiency in the centrifuge and a more rapid attainment of equilibrium conditions.

The rotor of FIG. 2 may be designed as follows: It is assumed that it is to work at a predetermined angular velocity carrying a predetermined liquid or gaseous load and that it is required that the tensile stress under these conditions should have the same value throughout the metal of the rotor, excepting the boss 28.

In FIG. 4 there is shown a fragment of the rotor of FIG. 2 in which a part of a span 34 is shown divided into elements *a*, *b*, *c* (of which *a* is at the mid-point of the span) and in FIG. 5 these elements are shown enlarged and with a reduced rotor diameter for compactness. Fluid within the rotor is indicated at 40.

Considering the element *a* of metal and fluid, the centrifugal force acting thereon along the dotted line 41 is balanced by tensions *t* along the centre line of the metal 34 resolved along the line 41. If the radius of curvature of the centre line of the metal has (at the mid-point of the span) been fixed at say one eighth of the maximum diameter of the rotor, then the directions of the tensions *t* are known and if the element *a* is circumferentially short may be assumed to pass through the centre of the metal part of the element *a*. The magnitude of the tensions *t* can be calculated, assuming a radial thickness of the metal element which will sustain the total tension with the desired stress in the metal.

Alternatively, if the radial thickness of the metal of element *a* is predetermined, the radius of curvature of the centre line thereof can be calculated graphically or arithmetically.

When the magnitude and direction of the force with which element *a* acts on element *b* is known, the magnitude and direction of the force with which element *b* acts on element *c* can be determined, the thickness of metal in each case being calculated from the tension exerted on the previous element.

In this way the thickness of and the direction of the tensile force upon each element of the span, in turn, can be determined until the centre line of the web 33 is reached. The thickness of the web is then made such that, working at the required stress, it will withstand the radial tension necessary to sustain two half spans 34 and the load 40. The thickness of the web will increase towards the axis 25 owing to the increase in the radial tension in the web caused by the centrifugal force acting on the part of the web between the point under consideration and the outer end thereof.

It may be noted that with two exactly similar rotors, one twice the size of the other, both rotating at the same

peripheral speed and carrying the same mass of load, the stress in the metal of the larger rotor will be less than the stress in the metal of the smaller rotor. If the smaller rotor has been designed to have uniform stress throughout, except in the boss 28, the stress in the larger rotor for the same load, or even for twice the load, will not be uniform throughout but will everywhere be of a value less than in a corresponding position of the smaller rotor. It is, therefore, advantageous to use as large a rotor diameter as other constructional considerations permit.

Rotors of short axial length and up to about 6 inches in diameter, may be machined out of the solid bar and dynamically balanced. When this method of construction is unsuitable, the rotors may be made in any of the following ways.

(1) A number of rotors of short axial length, or laminae whose major surfaces are perpendicular to the axis of rotation 25, may be stamped, machined or otherwise given the correct shape and the short rotors or laminae may then be joined together by brazing, copper-brazing or otherwise.

(2) The rotor of FIG. 2 may be constructed by forming the boss 28 and webs 33 separately and joining them together or these parts may be cast, forged or otherwise formed in one piece, and the spans 34 may then be joined to the ends of the webs 33. The joining may be by welding, copper-brazing in hydrogen or by any other method giving a strong joint.

(3) The rotor may be cast, with or without some form of machine finishing.

In any case the rotor may be surface-treated according to the nature of the fluid to be centrifuged so that it offers adequate resistance to corrosion. If laminae are used and if these are of a material such that its strength depends upon the direction of the applied load, the directions of least strength in successive laminae should not coincide with one another.

I claim:

1. A rotary hollow metal body mounted for rotation at a high speed about an axis, said body comprising a boss containing said axis, a plurality of webs fixed to and extending radially from said boss, each of said webs having a radial length which is uniform in a direction extending parallel to said axis, the radial lengths of all of said webs in any plane perpendicular to said axis being the same whereby the outer ends of said webs terminate in an imaginary circular cylindrical surface, and a plurality of spans fixed to the outer ends of said webs, the ends of said spans being joined to form a continuous wall encircling said webs, and each of said spans, at every section of said rotary body defined by planes perpendicular to said axis, having a shape which a span of the same dimensions but of flexible material would assume if subjected to the centrifugal loading which is exerted upon the span of the rotary body when said body is rotating about said axis.

2. A rotary hollow metal body mounted for rotation at a high speed about an axis, said body comprising a boss containing said axis, a plurality of webs fixed to and extending radially from said boss, the radial lengths of all of said webs in any plane perpendicular to said axis being the same whereby the outer ends of said webs terminate in an imaginary circular surface, and a plurality of spans fixed to the outer ends of said webs, the ends of said spans being joined to form a continuous wall encircling said webs, and each of said spans, at every section of said rotary body defined by planes perpendicular to said axis, having a shape which a span of the same dimensions but of flexible material would assume if subjected to the centrifugal loading which is exerted upon the span of the rotary body when said body is rotating about said axis.

3. A rotary hollow metal body as set forth in claim 2 wherein the radial thickness of the material of the spans

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decreases progressively from the ends thereof fixed to said webs to the centers of said spans.

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