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(54) Supporting cap and spacer for centrifuge tubes.

(57) A modular spacer concept is disclosed for use in centrifuge bores. The arrangement is such that various sizes of tubes (22) are available to allow for different amounts of fluid which may be inserted therein for centrifugation. A plurality of substantially identical spacers (40) are provided, each of which has an effective length equal to a predetermined standard difference in tube sizes. The lower surface (42) of each spacer has a concave center portion adapted to fit the convex center portion of the upper surface of a tube (22), and the upper surface (44) of each spacer has a convex center portion adapted to fit the concave center portion of the lower surface (42) of a substantially identical spacer. The cap has an annular skirt which engages the top of the tube and which is sufficiently thick in cross-section to prevent deformation of the cap.

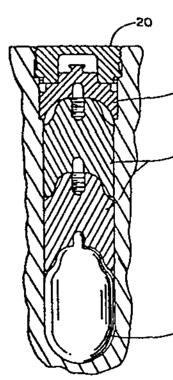

FIG. 3

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SUPPORTING CAP AND SPACER FOR CENTRIFUGE TUBES

Background of the Invention

This invention relates to the centrifuge field, and particularly to the sample retaining means used in the bores, or cavities, of a centrifuge rotor.

The present invention appears to have its primary advantages in conjunction with the use of "Quick Seal" sample-containing tubes, which are tubes having their cover areas formed integrally with their bodies, and sealed by fusion of a nipple, or neck, after it has been used for insertion of the fluid sample. Such tubes have proved to be highly advantageous, as compared with earlier open-top tubes, which had to be sealed with separate caps and which, therefore, had serious sealing problems.

The invention of "Quick Seal" tubes is disclosed in U.S. Patent Application of S.T. Nielsen S/N 912,698 titled "An Integral One Piece Centrifuge Tube", filed on June 5, 1978 and assigned to us; it is also disclosed in U.K. published patent application 2 021 982A.

Since "Quick Seal" tubes are thin-walled vessels in which the cover portion is integral with the body portion, the forces developed by centrifuge operation have a tendency to collapse the upper portion of the tube. Such tube-collapsing forces are due both to the hydraulic pressures inside the tube which act vertically on the tube during centrifugation, and to the "bucking" effect on the inner, or centripetal, portion of the tube if significant amounts of air are enclosed in the tube, either entrained in the liquid material or left in the tube because the liquid does not fill it.

In order to prevent deformation of "Quick Seal" tubes, certain precautions must be taken particularly in providing support for the upper surface of the tube. This may be accomplished by using a supporting cap which engages, and generally conforms to, the top of the tube, even though such a cap is not required for closing, or sealing, the tube.

In a vertical bore containing a tube which substantially fills the bore, the large upward forces inside the tube, generated by the hydraulic pressure, are normally opposed by a threaded plug that screws into a counterbore in the top of the rotor body. Such a threaded plug may have direct engagement with the top of the tube, or there may be a small cap inserted between the plug and the tube primarily for the purpose of partially insulating the tube from turning forces created while the plug is being screwed into, or out of, the rotor. If a smaller amount of fluid is to be centrifuged, it is highly desirable to use a smaller tube, in order to minimize the amount of air remaining in the sealed tube. Use of a shorter tube in a vertical bore requires a spacer to fill the space between the top of the tube and the threaded plug at the top of the bore, since the tube must receive direct support against the vertically acting hydraulic pressures. In order to make several different sample sizes usable in the same vertical rotor bore, it is desirable to have tubes of different lengths and, therefore, it is necessary to have spacers of different lengths, so that the space between the tube top and the threaded plug may be filled regardless of the size of the tube.

In a non-vertical bore, the centrifugal force can be relied on to hold the floating cap in supporting engagement with the top of the tube. Because such a cap is floating it will firmly engage the top of the tube regardless of the distance between the tube top and the upper end of the rotor cavity, or bore, which contains the tube.

The cap must be so designed as to be structurally self-sufficient in avoiding permanent deformation by the powerful centrifugal and hydraulic forces generated in the centrifuge. The tube supporting function of the caps has involved extreme stresses which have caused them to deform into substantially oval or elliptical shapes, and to take a set in the deformed shapes, rendering the caps difficult to extract from the rotor cavities, and useless for subsequent centrifuge operations.

Summary of the Invention

The present invention provides a modular spacer which acts as a supporting cap for the top of the sample-containing tube, and which is so designed that a plurality of identical spacers can be used if the size of the tube requires. The same spacer may also be used as the floating cap in an obliquely oriented rotor bore.

Each of the identically shaped modular spacers is so designed that its lower surface will engage either the top of the tube or the top of another spacer, and its upper surface will engage either the lower surface of another spacer or the retaining structure secured in the counterbore at the top of the rotor. In other words, the lower surface of each spacer, or cap, has a concave center portion adapted to fit the convex center portion of the upper surface of the tube, and the upper surface of each spacer, or cap, has a convex center portion adapted to fit the concave center portion of the lower surface of a substantially identical cap.

The present invention thus contemplates use of a plurality of sample-containing tubes of different sizes, which are alternately available for use depending on the amount of fluid material to be enclosed in each tube. The available tubes are of different effective lengths, each tube length differing from the others by a predetermined standard distance. A plurality of substantially identical spacers are provided, each of which has an effective length equal to the predetermined standard difference in tube sizes, thereby permitting the use of whatever number of spacers is required to fill the bore.

In order to retain the essentially spherical shape of the upper portion of the tube, which is desirable both from a functional and from a manufacturing standpoint, the center portion of the tube upper surface is essentially dome-shaped, and the floating cap has in its lower surface a concave recess which engages and substantially conforms to the dome-shaped surface of the tube. The cap has an annular axially extending peripheral portion which resists deformation of the cap and provides an annular end surface against which the peripheral area of the tube is pressed during centrifugation.

Brief Description of the Drawings

Figure 1 is a schematic partial sectional view of a centrifuge rotor having a plurality of tube-containing cavities vertically oriented therein;

Figure 2 shows the same rotor cavity as Figure 1, in which a shorter tube is mounted, in combination with a single modular spacer;

Figure 3 shows the same rotor cavity as the preceding two figures, in which the shortest standardized tube is mounted, together with two of the substantially identical modular spacers;

Figure 4 shows an obliquely oriented rotor cavity in which a modular spacer is used as a floating cap on top of the tube; and

Figure 5 is a close-up cross-sectional view of the preferred modular spacer configuration.

Detailed Description of the Preferred Embodiment

As shown in Figure 1, a centrifuge rotor 10 has a plurality of circumferentially spaced bores, or cavities, 12 each adapted to retain a fluid sample during centrifugation. The bores 12 are vertically oriented, and are parallel to the spin axis 14 of the rotor. With this arrangement, the hydraulic pressures developed during centrifugation have an upward component which must be resisted by a closure member secured in the rotor body. For this purpose, a counterbore 16 is provided at the top of bore 12, having internal threads to engage a threaded plug 20 which closes the top of the bore.

In the version shown in Figure 1, a single sample-containing tube 22 is inserted in the bore 12. This is a "full-length" tube, which conveniently may have a length of three and one-half inches. Obviously other lengths may be chosen, but the specific dimension is stated in order to assist in explaining the inventive concept. The tube 22 is a "Quick Seal" tube of the type disclosed and explained in detail in Nielsen application S/N 912,698. Its cover, or top, portion 24 is formed integrally with its body portion 26 by a suitable process, such as blow-molding. In the center of the top portion 24 of the tube is a projection, or nipple, 28 formed initially as a tube-like extension through which the fluid sample is inserted into the tube, and then hermetically sealed by a suitable process, such as heat fusion. A substantially spherical upper surface of the tube is desirable from a purely functional standpoint, in that it causes minimum interference with the reorienting fluid which is being centrifuged.

In the structure shown in Figure 1, the upper surface 24 of the tube is formed on a radius substantially longer than the radius of bore 12, with the result that the tube top does not have a truly spherical shape. One advantage of the structure shown in Figure 1 is that it reduces the overall length of the tube, and thereby reduces the depth of the cavity in the member which engages the top of the tube. In the arrangement shown, a separate cap member 30 is provided between the top of the tube and the threaded plug 20. Cap 30 has a lower concave surface 32 which engages the top 24 of the tube, and at its center has an axially extending hole 34 which accommodates the nipple 28 on the tube. The upper surface of cap 30 engages the lower surface of plug 20, and, as shown, a recess 36 may be provided in the plug to receive a corresponding boss provided on the cap. The plug 20 and cap 30 could be combined into a single element, but their separation into two elements is preferable because it tends to avoid twisting tube 22 in the bore when the threaded plug 20 is screwed into and out of the bore.

Figures 2 and 3 disclose an important concept of the present invention. In each of those figures, a tube is used which is substantially smaller than the tube in Figure 1. The purpose of using smaller tubes is to match the tube size more closely to the amount of liquid to be centrifuged. If a user prefers to centrifuge a smaller amount of fluid than the full-size tube is designed for, having access to smaller tubes is highly desirable. This is true primarily because it is undesirable to include a significant amount of air in a sealed tube.

In vertical tube-containing bores the hydraulic pressure developed during centrifuging causes a large upward force which is opposed by the threaded plug 20 secured in the top of the bore. Where a shorter tube is used, the space between the top of the tube and the plug 20 must be filled by a suitable spacer which resists the upwardly acting hydraulic pressure.

Such a spacer is particularly vital where the tube is one of the "Quick Seal" types, which is a thin-walled vessel subject to bursting, or rupturing, unless it is adequately supported by contact with a cap or spacer engaging its upper surface.

In order to simplify the parts inventory required by a centrifuge user, while at the same time providing a useful range of tube sizes, the present invention provides a modular, or universal, spacer which can be used in combination with any of several standard tube sizes, each of which differs in length from the next tube size by an amount equal to the effective length of the modular spacer.

For example, it has been found convenient to provide tubes of three different lengths for use in the same rotors. A useful size selection comprises tubes of 1-1/2" length, 2-1/2" length, and 3-1/2" length. This permits a modular spacer to be used which has an effective length of 1 inch. Then the 3-1/2 inch tube will be used without a spacer, as shown in Figure 1. The next shorter tube, which is 2-1/2 inches long, will be used with a single 1 inch spacer in the same bore length having the same threaded plug. And the shortest tube, which is 1-1/2 inches long, will be used with two 1 inch spacers, which engage one another and convey the vertical force to the threaded plug.

Each modular spacer in Figures 2-5 is indicated by the numeral 40. Each such spacer is substantially identical with all the others, and it is so shaped that its lower surface 42 has a central concave portion which conforms to the central convex portion of the top of the tube, while its upper surface 44 has a central convex portion which is similar in shape to the central convex portion of the top of the tube, thereby causing the top of the spacer to fit the lower surface of another moduar spacer, if one is required.

The tube 22A in Figure 2 is one inch shorter than the tube 22 in Figure 1, and a single spacer 40 is located in Figure 2 between the top of tube 22A and the cap 30, which in turn engages threaded plug 20. The lower surface 42 of spacer 40 engages and substantially conforms to the upper surface of the tube 22A, in order to provide adequate structural support therefor. The specific shape of the modular spacer 40 and of tube 22A will be discussed in more detail below. The center portion of upper surface 44 of spacer 40 preferably conforms to the center of cap 30 (i.e., they are formed along substantially identical radii), but conformity of shape between spacer 40 and cap 30 over a wider area is not required, since the spacer is structurally stiff enough that it does not need a larger area of engagement with cap 30. Spacer 40 will normally be formed of a non-scoring plastic material; threaded plug 20 will generally be metallic; and cap 30 may be either metallic or plastic.

The tube 22B in Figure 3 is two inches shorter than the tube 22 in Figure 1, and therefore two spacers 40 are located in Figure 3 between the top of tube 22B and the cap 30. In order for the spacers to be interchangeable, each has a lower surface which substantially conforms to the top of the tube, and each has an upper surface designed to conform substantially to the lower surface of an identical spacer.

Figure 4 shows the use of modular spacer 40 in conjunction with a Quick Seal tube 22C which is located in an obliquely oriented rotor bore, i.e., a bore which inclines toward the spin axis. In such an inclined bore, the spacer 40 will float, i.e., it will not require a retaining plug, because the centrifugal forces and frictional forces retain the spacer in engagement with the tube. Although the same spacer shape is not required when the spacer floats, it is much simpler to provide support for the tube top in an oblique bore by using the same modular spacer as the one provided for use in vertical bore rotors. Thus, a single spacer structure can be used for tube-top-supporting purposes whenever such support is required.

The preferred structure of the modular supporting cap, or spacer, 40 is shown substantially enlarged in Figure 5. The concave portion of the lower surface of the cap or spacer should not extend out to its periphery because of structural weaknesses encountered in such a design. In other words, the spacer should have an annular skirt 46 which is sufficiently thick in cross-section throughout its length to resist deformation during centrifugation. As shown, the annular skirt 46 terminates in a substantially flat annular surface 48, against which the upper peripheral edge of the tube will be pressed during centrifugation. The shape of skirt 46 necessitates changing (in the manner disclosed herein) the top of the tube which conforms to the inner end of the cap, except that the tube contours are so curved as to avoid any sharp changes in the shape encountered by the gradient as it moves during centrifugation.

The particular configuration of the lower surface 42 and upper surface 44 of each spacer 40 can be varied without departing from the primary concepts of the present invention. However, the preferred shape is detailed in Figure 5. As seen in cross-section, the spherical center portion 50 of lower surface 42 is formed as an arc on a radius centered at 51; and the center portion 52 of upper surface 44 is formed as an arc on an equal radius centered at 53. The annular portion 54 of lower surface 42 adjoining center portion 50 is formed as arcs on much shorter radii centered at 55A and 55B; and the annular portion 56 of upper surface 44 adjoining center portion 52 is formed as arcs on equal radii centered at 57A and 57B. At the outer edge of each of the arcuate surfaces 54 and 56, it is convenient to reverse the shape of the curve by forming an arcuate portion on radii centered on the other side of the formed surface from the centers of the radii described previously. Thus, the annular portion 58 of lower surface 42 near the periphery thereof is formed as arcs on radii centered at 59A and 59B; and these arcs extend to the inner edge of the flat annular surface 48. The annular portion 60 of upper surface 44 near the periphery thereof is formed as arcs on radii centered at 61A and 61B; and these arcs, for reasons of manufacturing economy, preferably extend all the way to the outer cylindrical wall 62 of the spacer. The need for a flat annular surface does not exist at the upper end of the spacer; and the small gap which therefore remains between two mating spacers does not detract from the structural strength of the spacer-to-spacer engagement.

The following claims are intended not only to cover the specific embodiments disclosed, but also to cover the inventive concepts explained herein with the maximum breadth and comprehensive permitted by the prior art.

CLAIMS

1. In a centrifuge rotor having at least one cylindrical bore for receipt of a fluid sample, sample retaining means comprising:

a closed tube containing the sample and having a cylindrical body portion which generally conforms to the shape of the bore and an upper surface which has a generally dome-shaped center area; and

a cap engaging the top of the tube and having in its lower surface a concave recess which engages and substantially conforms to the dome-shaped center area of the tube upper surface;

the cap having an annular axially extending skirt which encircles the dome-shaped center area of the tube and which has sufficient cross-sectional area to prevent permanent deformation of the cap during centrifugation, said axially extending skirt terminating in a substantially flat annular surface.

2. The structure of Claim 1 wherein the upper surface of the tube has a peripheral area around the dome-shaped center area which during centrifuge operation is pressed against the adjacent annular surface of the skirt portion of the cap.

3. The structure of Claim 1 or Claim 2 wherein the upper surface of the cap has a convex center portion adapted to mate with a concave center portion of a lower surface of a substantially identical cap.

4. The structure of any of the preceding claims in which the cap is mounted in a substantially

vertical bore having a counterbore formed at the top thereof, and which structure also includes:

a closure member secured in the counterbore and in operative engagement with the modular cap to prevent the vertical displacement thereof.

5. The structure of any of Claims 1, 2 or 3 wherein the cylindrical bore in the rotor is at an angle such that centrifugal force tends to move the tube to the bottom of the bore and the cap is a floating member resting on the tube and free, except for the tube, to move toward the bottom of the cavity under the effect of centrifugal force.

6. The structure of Claim 5 wherein the cap is formed of material having a lower density than that of the fluid sample.

7. The structure of any of the preceding claims used in a modular system comprising:

a plurality of alternatively available sample-containing tubes for placement in the bore, said tubes being of different effective lengths, each tube length differing from the others by a distance "X";

a plurality of substantially identical spacers, each having an effective length equal to the distance "X"; and

a plug adapted to be secured in the top of the bore to retain the tube and one or more of the spacers therein.

8. The structure of any of the preceding claims wherein the peripheral area of the upper surface of the tube, which encircles its dome-shaped center area, is shaped to generally follow the corresponding portion of the cap, but has first a convexly curved

shape adjacent the dome-shaped center portion and then a concavely curved shape adjacent the cylindrical body portion, thereby minimizing changes in the cross-sectional area encountered by reorienting fluid.

9. The structure of any of the preceding claims wherein the tube is so formed that its body portion and its upper closing portion are integrally formed from the same material, which has been fused to seal the tube after insertion of the fluid sample.

10. The structure of any of the preceding claims wherein the tube upper portion has a nipple at its center, and the center of the cap has an axial hole into which the nipple extends.

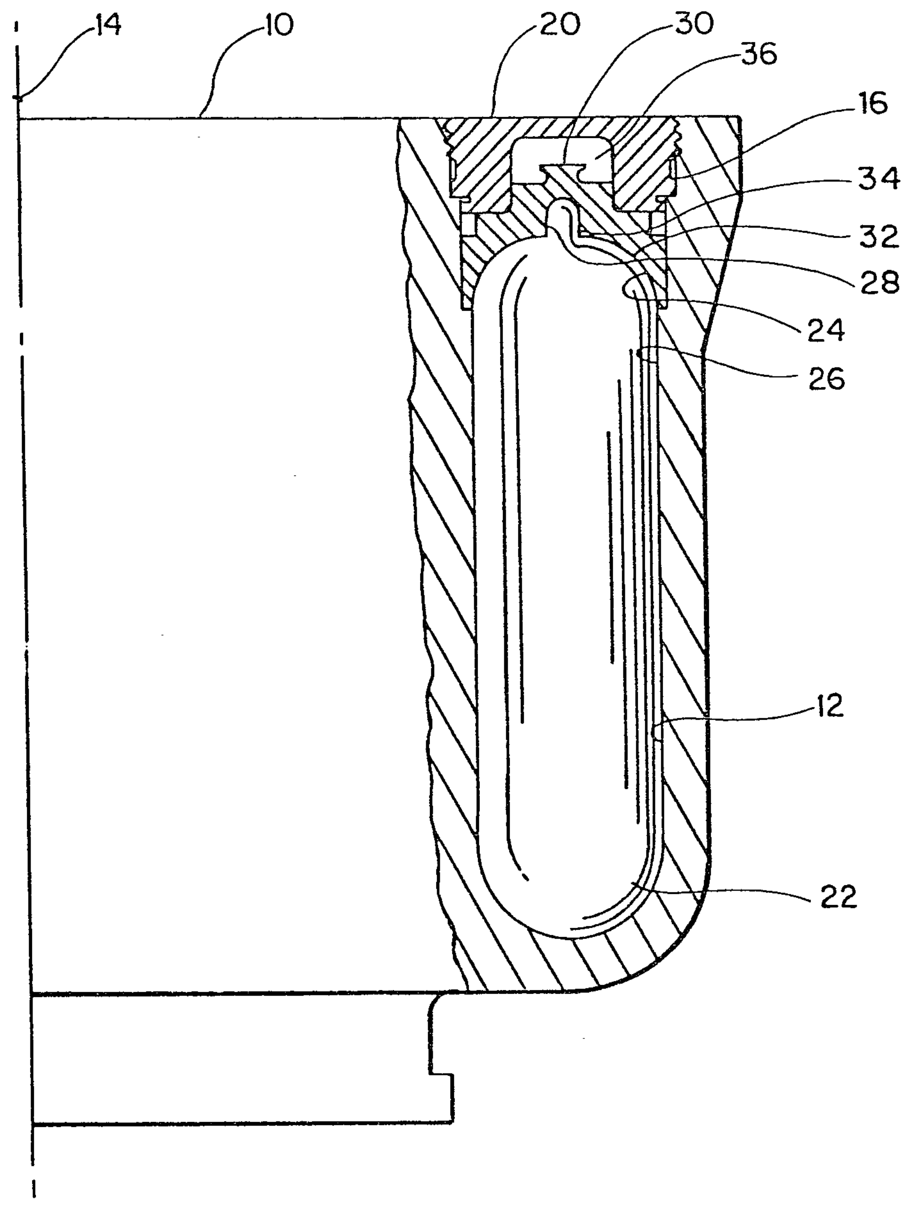


FIG. 1

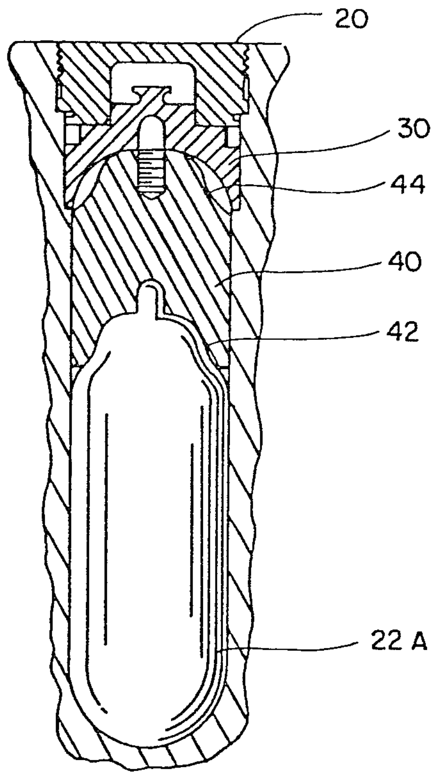


FIG. 2

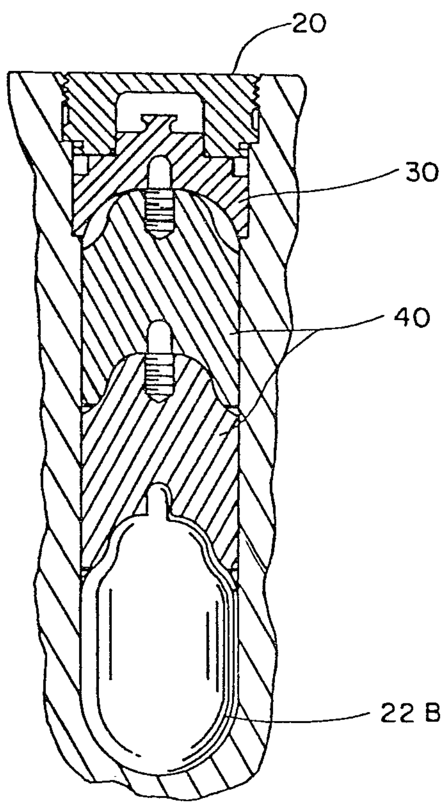
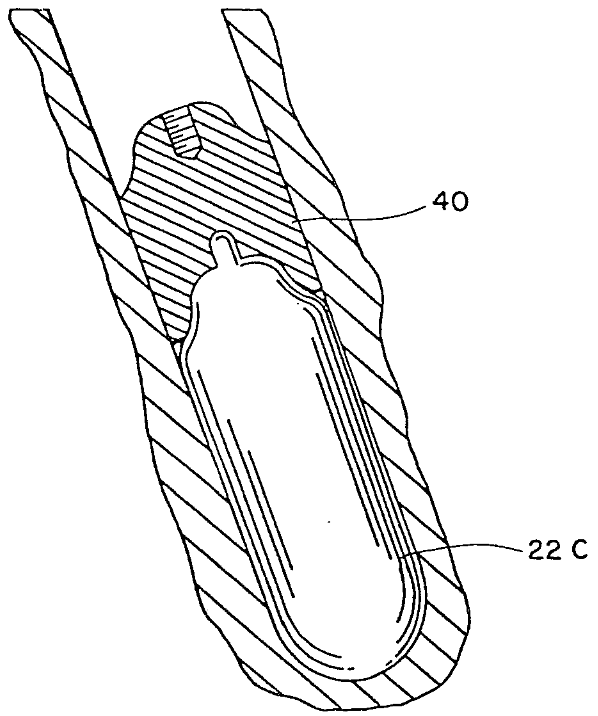


FIG. 3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22 C

FIG. 4

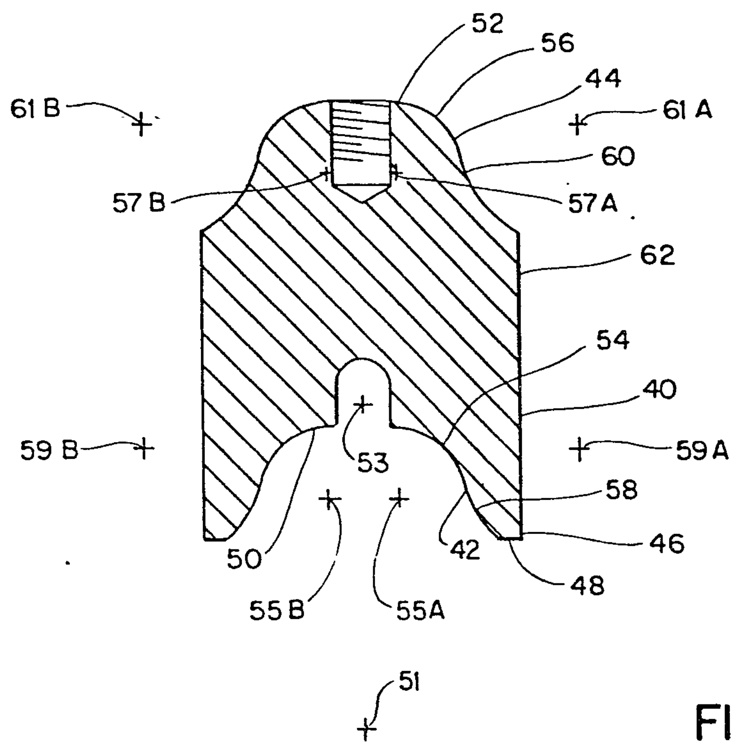
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FIG. 5

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European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 81 30 0470

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
AD	GB - A - 2 021 982 (BECKMAN) * Page 2, lines 83-128; pages 3-5 *	1,2,4, 5,9, 10
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A	US - A - 3 071 316 (PIEMONTE) * Column 2, lines 28-37 *	1,2,5
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A	US - A - 3 672 564 (SCHLUTZ) * Column 3, lines 5-20 *	1

CLASSIFICATION OF THE APPLICATION (Int. Cl.3)

B 04 B 5/04

TECHNICAL FIELDS SEARCHED (Int. Cl.3)

B 04 B
B 01 L

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	05-06-1981	VERDONCK

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