United States Patent [19]

Unger et al.

[11] **3,724,747**

[45] **Apr. 3, 1973**

[54] **CENTRIFUGE APPARATUS WITH MEANS FOR MOVING MATERIAL**

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[22] Filed: **Mar. 10, 1972**

[21] Appl. No.: **233,538**

[30] **Foreign Application Priority Data**

Mar. 15, 1971 Sweden 3309/71
Mar. 15, 1971 Sweden 3310/71

[52] **U.S. Cl.** ....**233/3,** 233/14 R, 233/19 R, 233/26

[51] **Int. Cl.** **B04b 1/00**

[58] **Field of Search** ....233/3, 20 R, 20 A, 27, 28, 233/19 R, 19 A, 26, 46, 47 R, 14 R

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[57] **ABSTRACT**

A centrifuge for batch treatment of a liquid, particularly blood, such as for separating blood into fractions of different densities and/or for washing blood cells suspended in a liquid, comprises closed collapsible containers in the centrifuge rotor. Resilient tubing interconnects the containers and a peristaltic pump member mounted on and rotating with the centrifuge rotor acts on the resilient tubing to selectively move liquid therethrough from one container to another and prevent liquid flow through the resilient tubing.

5 Claims, 4 Drawing Figures

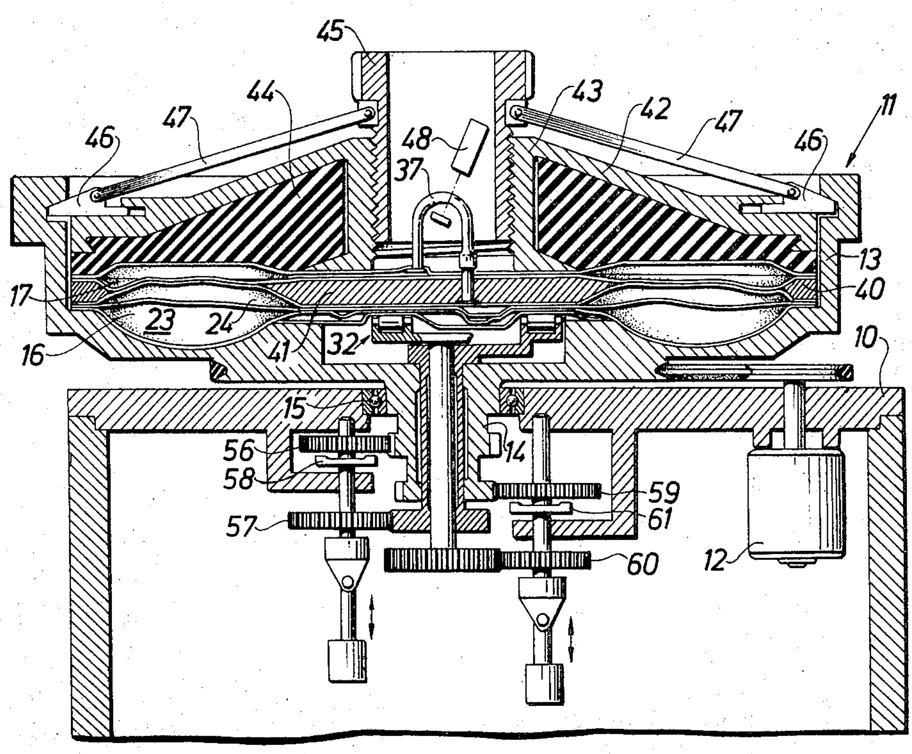

Fig. 1

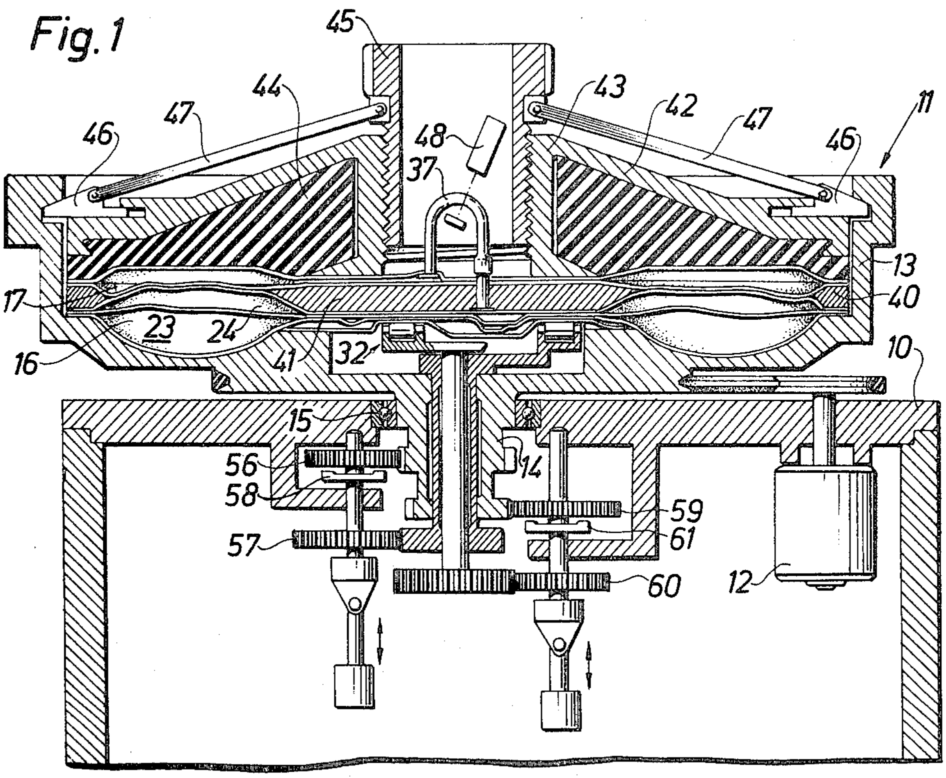
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Fig. 2

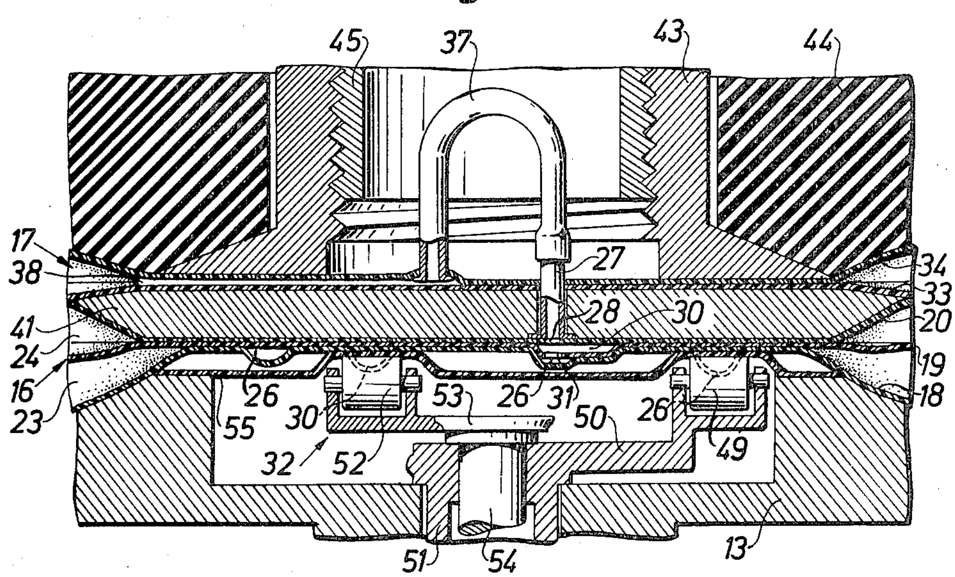
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Fig. 3

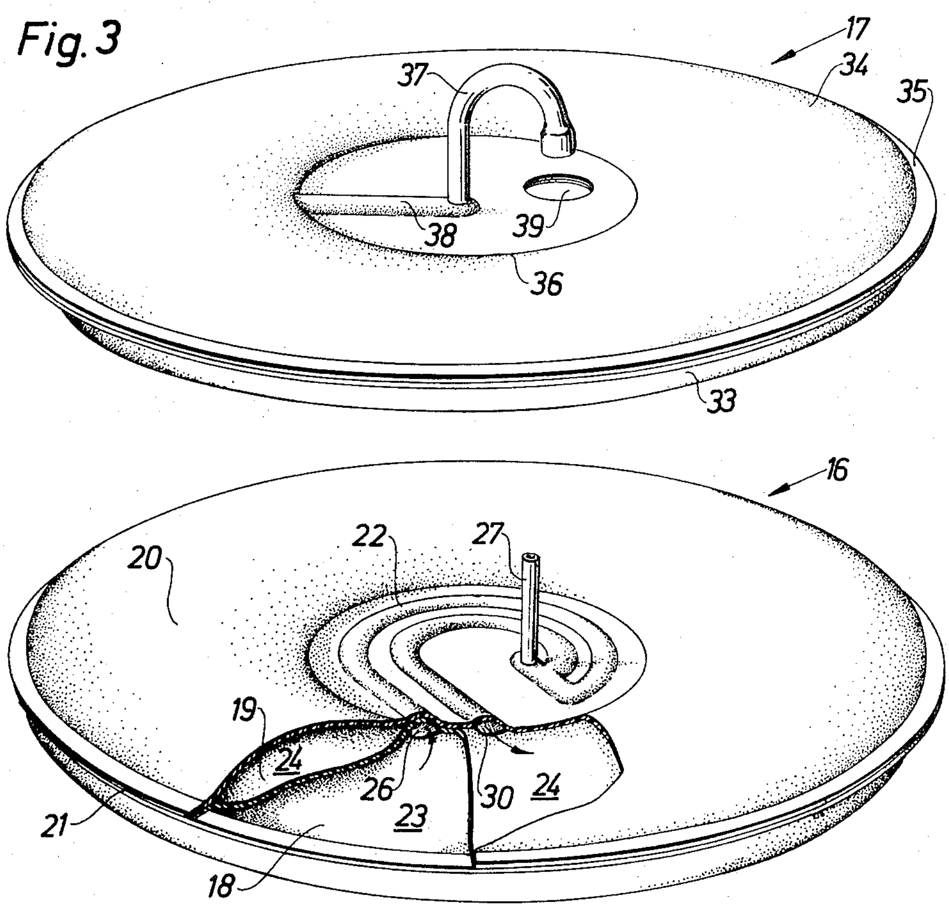
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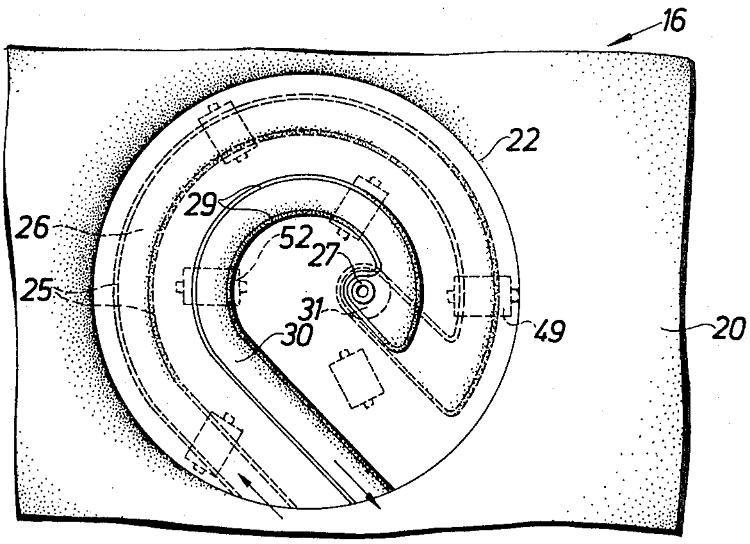
Fig. 4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CENTRIFUGE APPARATUS WITH MEANS FOR MOVING MATERIAL

This invention relates to centrifugal treatment of liquid and more particularly to equipment for centrifugally treating discrete quantities of a liquid by separating it into fractions of different densities and, where desired, by washing solid particles suspended in liquid. The invention has particular application to the centrifugal treatment of blood and the present disclosure will be devoted primarily to this application. It should be understood, however, that the invention is applicable to the treatment of other liquids than blood. It should also be noted that the term "liquid" as used in this specification embraces not only true liquids but also other materials resembling liquids such as the semi-liquid mass of blood cells obtained from whole blood after separation of the plasma.

It is known to treat discrete quantities of blood in a closed system of collapsible containers in a centrifuge rotor. Thus, one container may initially hold a batch consisting of either a mixture of whole blood and a liquid preservative or a suspension of red blood cells in a liquid preservative and a second container may initially hold a quantity of a wash solution while a third container is initially empty. The containers are interconnected through conduits and during the treatment plasma and/or preservative from the first container is passed into the empty third container and temporarily replaced by wash solution from the second container. After agitation of the contents of the first container the used wash solution and the material washed off from the blood cells is passed into the third container leaving the washed red cells in the first container.

The use of collapsible closed containers for the blood, for separated fractions and for wash solution enables the treatment to be carried out under sterile conditions since the containers can be interconnected in a closed system to communicate with each other without their contents coming into contact with the ambient atmosphere or exterior surfaces. The transfer of liquid between the containers has presented problems, however, since the transfer normally has to take place while the centrifuge rotor and the container system rotate at high speed.

A general object of the present invention is to provide improved means for effecting and controlling the transfer of liquid between the containers.

A more specific object in accordance with the foregoing general object is to provide a centrifuge in which the rotor supports a pump for displacing liquid between the containers.

Another object is to provide a centrifuge which can be loaded with the containers and made ready for operation with a minimum of manual labor.

In one embodiment of the invention these and other objects are realized in a centrifuge having a rotor, an assembly of collapsible closed containers disposed in and rotating with the rotor, a collapsible conduit which provides a path for the flow of liquid between the containers, and a peristaltic pump member which is mounted on he rotor and adapted to rotate with the rotor and the container assembly. The peristaltic pump member continuously acts on the collapsible conduit and when liquid is to be transferred from one container to another, the peristaltic pump member is caused to rotate slowly with respect to the rotor and the container assembly to displace liquid through the conduit. When the peristaltic pump member is stationary with respect to the rotor and the container assembly, it compresses the conduit to block flow therethrough.

THe above and other objects and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying diagrammatic drawings.

FIG. 1 is a view in vertical section of the rotor and associated parts of a centrifuge constructed in accordance with the invention;

FIG. 2 is an enlarged view corresponding to the central portion of FIG. 1;

FIG. 3 is an exploded partly cut away perspective view of the container assembly in the centrifuge shown in FIGS. 1 and 2;

FIG. 4 is a plan view of the central portion of the two-compartment container shown in the lower portion of FIG. 3.

The centrifuge diagrammatically illustrated in FIG. 1 has a frame **10** supporting a centrifuge rotor **11** for rotation about a vertical axis at high speed, e.g., 3000 rpm, by means of a motor **12**. Rotor **11** includes a bowl **13** having a depending hollow journal member **14** mounted in a ball bearing **15** in frame **10**. The rotor bowl and most other elements of the rotor are circular in plan view.

Rotor bowl **13** houses a container assembly the details of which are best seen in FIG. 3. It includes a lower two-compartment container **16** supported on the bottom wall of bowl **13** and an upper single-compartment container **17** supported on top of container **16**. Both containers are generally disk shaped and concentric with the rotor bowl. They are both closed, disregarding openings for the introduction and removal of liquid, and made of a thin and flexible sheet material so as to be collapsible. The sheet material may be, for example, a laminate of polyethylene and polyester having a total thickness of about 0.1 millimeter.

Lower container **16** is made of three circular sheets **18,19,20** disposed one on the other and sealingly joined along their peripheries by a continuous heat seal **21** and at their central portion by another circular heat seal **22**. Lower and central sheets **18,19** define between them a compartment **23** which initially holds wash solution and central and upper sheets **19,20** define between them a compartment **24** which is initially empty.

In the central portion of container **16**, heat seals **25** (marked by closely spaced dash lines in FIG. 4) joining sheets **18,19** define a collapsible conduit **26** through which wash solution in compartment **23** can flow to a short connecting tube **27** secured to upper sheet **20** around an opening **28** in the latter via an opening **31** in sheet **19** (see also FIG. 2). Similar heat seals **29** (marked by closely spaced full lines in FIG. 2) joining sheets **19,20** define another collapsible conduit **30** through which liquid can flow from connecting tube **27** to compartment **24**. Portions of conduits **26,30** extend along two concentric circles and cooperate with a pump **32** described in more detail hereinafter. This pump is operable to produce the liquid flow and to block the conduits when flow is not desired. Heat seal **22** prevents liquid in the two compartments from entering the central container portion except through the conduits.

Upper container 17 initially holds a quantity of blood cells suspended in a liquid preservative. It consists of two sheets 33, 34 which are joined by a heat seal 35 at their peripheries and a heat seal 36 at their central portions so that they define between them an annular compartment. A connecting tube 37 communicates with this compartment through a conduit 38 defined by heat seals. An opening 39 in the central portion permits tube 37 to be connected with tube 27 of container 16.

Conduits 26 and 30 as well as conduit 38, owing to the characteristics of the material and the manner in which they have been produced, have a strong natural tendency to close themselves. Thus, in order that they may permit the liquid in the containers to pass through them, the liquid must be subjected to a substantial pressure. Therefore, no special precautions are necessary to prevent unwanted flow through the conduits during manual handling of the containers.

Referring again to FIG. 1, a filler ring 40 and a backing plate 41 are disposed between containers 16 and 17. Connecting tube 27 extends through an opening in the backing plate and is connected to the connecting tube 37.

Rotor 11 includes a cover assembly with a rigid cover plate 42 which has an internally screw-threaded boss 43 and holds an annular body 44 made of soft rubber mixed with lead granules so as to have higher specific gravity than the liquids in the containers. A clamping mechanism having an externally screw-threaded sleeve 45 screwed into boss 43 and a number of circumferentially distributed wedges 46 connected to the sleeve through rod 47 cooperates with cover plate 42 and bowl 13 to hold down the cover assembly against the containers. A photoelectric detector 48 mounted in sleeve 45 signals the presence of red blood cells in connecting tube 37.

Pump 32 referred to above is of the well-known peristaltic type which has a plurality of rollers moved in a circular path to progressively collapse a resilient conduit so as to displace liquid in the conduit. It has two concentric and independently movable circular groups of rollers, each comprising three rollers spaced apart 120°. The outer group of rollers 49 are rotatably mounted on an outer rotor member 50 secured to a hollow shaft 51 which is concentric with rotor 11. These rollers cooperate with conduit 26. The inner group of rollers 52 are rotatably mounted on an inner rotor member 53 secured to a shaft 54 extending coaxially through shaft 51. These rollers cooperate with conduit 30.

As best seen in FIG. 2, rollers 49 and 52 engage conduits 26 and 30 through a flexible diaphragm 55 to locally compress and close these conduits against backing plate 41.

Rotor members 50 and 53 normally are stationary with respect to the rotating centrifuge rotor and the containers but when desired they can be slowly rotated with respect to the centrifuge rotor during rotation of the latter. Positive rotational movement of rotor member 50 is derived from journal member 14 of rotor bowl 13 by means of a gear 56 engaging a gear on the journal member and another gear 57 engaging a gear on hollow shaft 51. Gears 56 and 57 are mounted for rotation about a common axis but normally there is no driving connection between them. However, a magnetic clutch 58 can be actuated to cause these gears to rotate in unison so as to bring about slow rotation of rotor member 50 with respect to container 16 (clockwise as seen from above in FIGS. 1, 2 and in FIG. 4). Similarly, positive rotational movement of rotor member 53 (anti-clockwise) is derived from journal member 14 through gears 59,60 and a clutch 61.

The procedure for the treatment of the blood cells in container 17 will now be described. Rotor 11 is assumed to be stationary but assembled as shown in FIG. 1, although compartment 24 of container 16 is empty so that sheets 19 and 20 engage each other face to face under the influence of pressure from rubber body 44. Thus, the peripheral portions of the containers are clamped between the bottom of bowl 13 and filler ring 40 and between the latter and rubber body 44. The central portions of the containers are clamped between the rollers of pump 32 and the lower end of boss 43 of cover plate 42. The rubber body in conjunction with the shape of the parts ensure that unwanted air pockets adjacent the containers are virtually eliminated.

Rotor 11 is then caused to rotate with clutches 58,61 disengaged so that pump rotor members 50,53 rotate in unison with the centrifuge rotor owing to the friction between these rotor members and diaphragm 55 and other parts of the centrifuge rotor. Under the influence of the centrifugal forces, the heavy soft rubber of body 44 is forced outwardly to apply an external pressure to containers 16,17. Owing to the arrangement and shape of the parts, this pressure forces the liquid in the containers inwardly and causes conduits 26,30 to assume the expanded form shown in FIG. 2. However, since the rollers of the rotor members are stationary with respect to the rotor and the containers and compress the conduits, no liquid is permitted to pass through the latter.

The centrifugal field, which may be of the order of 1,000 g, causes the formation of fractions of different densities in container 17, that is, the red blood cells accumulate in the radially outer portion of container 17 while the lighter preservative liquid is collected in the radially inner portion. Clutch 61 is then engaged to cause inner rotor member 53 to rotate anticlockwise (FIG. 4) with respect to the centrifuge rotor and the containers so that the preservative liquid is pumped from container 17 into compartment 24 of container 16 through conduit 38, connecting tubes 37,27 and conduit 30. Since outer rotor member 50 is still stationary with respect to the centrifuge rotor and the containers, the preservative liquid is prevented from flowing through conduit 26.

When detector 48 signals the presence of red blood cells in tube 37, clutch 61 is again disengaged and clutch 58 engaged so that outer rotor member 50 is caused to rotate to pump wash solution from compartment 23 into container 17 through conduit 26. tubes 27,37 and conduit 38 while inner rotor member 53 is held stationary to prevent flow through conduit 30. When a sufficient amount of wash solution has been transferred, clutch 58 is disengaged so that both conduits 26,30 are closed whereupon rotor 11 is rapidly braked (by means not shown) to low speed to agitate the contents of container 17 and thoroughly mix the wash solution and blood cells.

THe wash solution is then separated from the blood cells and transferred to compartment 24 of container 16 in the same manner as has been described for the preservative liquid. The washing step described above is repeated as many times as necessary and when the treatment is completed, container **17** contains a concentrate of washed blood cells while container **16** contains liquid preservative and used wash solution in compartment **24**. Compartment **23** may be empty or contain a residue of wash solution.

It will be appreciated that conduits **26,30** cooperating with pump **32** need not necessarily be integrally formed with container **16** as described but may be formed by separately attached flexible tubes. However, the described integral conduits offer significant advantages from a manufacturing as well as from a handling point of view.

What is claimed is:

1. A centrifuge for separating liquid into fractions of different densities, comprising a centrifuge rotor, a plurality of collapsible closed containers disposed in the centrifuge rotor for rotation therewith, a first one of the containers being adapted to initially hold a discrete quantity of liquid to be treated in the rotor and a second one being adapted to receive a fraction of lesser density from said first container, collapsible conduit means defining a flow path for conveying liquid between said first and second containers, and peristaltic pump means mounted on the centrifuge rotor for rotation therewith and acting on the conduit means to selectively move liquid through the conduit means and prevent liquid flow through the conduit means.

2. A centrifuge as set forth in claim **1** in which the peristaltic pump means includes pump rotor means mounted for rotation with respect to the centrifuge rotor about the axis of rotation of the latter and selectively operable means for causing rotation of the pump rotor means with respect to the centrifuge rotor.

3. A centrifuge as set forth in claim **2** in which the pump rotor means comprises two concentric rotors which are independently rotatable with respect to the centrifuge rotor, one of said rotors acting on a first collapsible conduit for transferring liquid to the first container and the other acting on a second collapsible conduit for transferring liquid from the first container.

4. A centrifuge as set forth in claim **1** in which the containers are generally circular and disk shaped containers which are disposed one on the other and concentric with the axis of rotation of the centrifuge rotor and in which a resilient member is disposed in the centrifuge rotor to apply during rotation of the latter an external pressure to the containers which is proportional to the speed of rotation of the centrifuge rotor.

5. A centrifuge as set forth in claim **4** in which the resilient member is made of a soft material adapted to have a specific gravity higher than that of the liquid to be treated.

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