

Suspension system for a flexible optical membraneTechnical Field

This invention relates to a suspension system for holding under tension a flexible membrane employed as a boundary surface of a liquid lens of adjustable focus or a flexible membrane mirror.

Background of the Invention

5 A liquid lens consists of at least one flexible transparent membrane which defines a boundary surface of a space that can be filled with a liquid. The liquid can be at a higher or lower pressure than the medium (usually air) contacting the other side of the membrane,
10 the pressure difference across the membrane causing it to curve so that the liquid-filled space functions as a lens.

 A membrane mirror consists of a flexible membrane suspended in a frame of circular or other shape and with
15 a reflective coating on one or both sides. Pressure applied to the membrane causes it to assume an appropriate conformation and allow the reflective coating to function as a mirror.

 For each device, the membrane requires to be appropriately supported while the required shape-deforming pressure is applied to it. The present invention provides
20 a method of supporting a membrane, forming part of a liquid lens or flexible mirror, under tension and thus provides improved liquid lenses and mirrors.

Summary of the Invention

25 According to one aspect of this invention, the boundary surface of a liquid lens or flexible mirror is defined by a flexible membrane supported between two

resilient rings confronting one another, a circumferential zone of each ring surrounding the said boundary surface being compressed against the membrane, the pair of rings together serving to generate a radially outwardly directed tension in the membrane defining said boundary surface.

Conveniently the resilient rings are identical rings of elastomeric material of circular cross-section (known as O-rings) but identical rings of elastomeric material of non-circular cross-section can also be used.

10 It is also possible to use rings of different cross-sections on the opposite sides of the membrane and even rings of somewhat different diameters, provided confronting zones are produced around the boundary surface.

15 In place of solid O-rings, hollow O-rings can be used. These can be divided into two or more sealed sections of the same or different lengths whereby the properties of each section can be altered by gas or liquid pumped into them. By varying the pressure in different sections, unequal radial tensions can be induced in the supported membrane. This allows controllable compensation for unequal forces acting on the membrane, such as centrifugal forces (if the boundary surface is part of a rotating system) or gravitational forces.

25 The resilient ring may be held in its supporting frame but not attached to it. However, the ring may be bonded to a supporting frame or even be an integral part of it. Thus, for example a moulded frame of plastics material may have an extrusion with a semi-circular cross-section or a cross-section of some other appropriate shape extending from the frame in a position in which the resilient ring is required. To ensure adequate resilience, the extruded ring may be hollow.

35 Two identical resilient rings can be supported opposite one another in a frame and the membrane placed between the two rings. Pressure can be applied to the

rings via the frame to cause the line of contact each ring makes with the membrane to become an annular zone producing an outwardly directed radial tension at all points in the membrane, and thus holding it in a flat condition under tension.

The compression forces applied at different parts of the circumference of the annular frame can be varied. This will cause different radial tensions in different parts of the membrane and allow controllable compensation for unequal forces which might be acting on the membrane (such as the centrifugal or gravitational forces mentioned above).

The force on the supported membrane at any point where the rings contact it, is determined by the compression forces acting on the resilient rings and the diameter and cross-sectional shape of the rings. The local force on the resilient rings may be altered by changing any of these parameters.

Brief Description of the Drawings

The invention will now be further described, by way of example, with reference to the accompanying drawing, in which:

Figure 1 shows, in schematic cross-section, a liquid lens in accordance with this invention,

Figure 2 shows, in cross-section, an alternative form of resilient ring for supporting a membrane in the lens of Figure 1, and

Figure 3 illustrates the mode of operation of the resilient rings in supporting the membrane.

Description of Preferred Embodiments

Figure 1 shows a liquid lens formed between two

flexible membranes 10 and 11. The membranes in this example are of high-grade plastic foil (e.g. that known under the Trade Mark "Melinex") and have a thickness of some twelve microns. Each membrane is clamped between a pair of O-rings 13-16 supported in an annular frame made up of a body 17 and two end caps 18, 19. The O-rings are received in grooves in the frame and these are sized to ensure each O-ring is compressed (e.g. by 380 to 500 μ m - 15 to 20 thou) against the respective membrane.

The body 17 is provided with a through-passage 20 through which a transparent liquid is fed into a space 21 defined within the body 17 between the membranes 10 and 11. A syringe (part shown at 22) can be connected to the passage 20 to vary the volume of liquid in the space 21 and thus vary the shape of the membranes 10, 11. The chain line 10a shows how the membrane 10 might appear with a reduced pressure in the space 21 and the line 11a how the membrane 11 might appear with a supra-atmospheric pressure in the space 21.

Each end cap 18, 19 is clamped to the body 17 by a number of fixing means 23. One of the fixing means has been shown as a screw 24 threaded into the body 17 and compressing the O-rings against the respective membrane via a spring 25. The spring 25 can be omitted and the screw 24 can be replaced by U-clamps or other fixing means.

Figure 2 shows a scrap section through part of the frame of a liquid lens, the membrane being shown at 10', one end cap at 18', part of the body at 17', and the sealing rings at 13', 14'. In this case, the rings 13', 14' are of non-circular cross-section and the grooves locating them are inclined to the axis of the aperture in the end cap 18'.

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Figure 3 shows the cross-section of two O-rings 15', 16' with a membrane 11' grasped between them. When downward pressure is applied on the upper ring 15' at A, and upward pressure on the lower ring 16' at B, the resultant forces in the plane of the membrane 11' acting at the position of contact, C, tend to move this outward, in the direction of the arrow D. This causes radial stretching of the membrane 11'.

The membrane 10 (11) can be silvered on either or both of its upper or lower surface to create a mirror of variable curvature. In the case of a mirror, one of the membranes can be replaced by a non-flexible plate closing off the volume 21 and in the case of a lens, one of the flexible membranes 10 or 11 can be replaced by a rigid lens to make a two-part combination lens, one part of which is a liquid lens. Clearly locating a rigid lens in the space 21 between two flexible membranes will give rise to a three-part combination lens, the two outer parts of which are liquid lenses. Other combinations of liquid/solid lenses are clearly possible.

It is also possible to have liquid on the side of the membrane 10/11 outside the space 21, the latter containing a gas or a liquid with a different refractive index from that appearing outside the space 21.



CLAIMS

1. A suspension system for a flexible membrane serving as a boundary surface of a liquid lens or a flexible membrane mirror which system comprises two resilient rings confronting one another, a circumferential zone of each ring surrounding the said boundary surface being compressed against the membrane, the pair of rings together serving to generate a radially outwardly directed tension in the membrane defining said boundary surface.

2. A system as claimed in claim 1, in which identical rings of elastomeric material are used on both sides of the membrane.

3. A system as claimed in claim 2, in which each ring is of circular cross-section.

4. A system as claimed in claim 3, in which each ring is an O-ring supported in a groove in a frame.

5. A system as claimed in claim 4, in which each O-ring is compressed by 380 to 500 μ m against the membrane by pressure applied to the frames.

6. A system as claimed in any preceding claim, in which two identical resilient rings are supported opposite one another in a frame with the membrane placed between the two rings, and in which pressure is applied to the rings via the frame to cause the line of contact each ring makes with the membrane to become an annular zone producing an outwardly directed radial tension at all points in the membrane, and thus holding it in a flat condition under tension.

7. A suspension system as claimed in claim 1, in which each ring is of non-circular cross-section and is located in a groove surrounding an aperture in a respective annular frame member, each groove being inclined to the axis of the aperture in the respective



annular frame member.

8. A suspension system as claimed in claim 1, in which each resilient ring is of hollow cross-section and means is provided to modify the pressure existing
5 within each ring.

9. A suspension system as claimed in claim 8, in which each ring is divided into sections and different pressures are maintained in the different sections.

10. A suspension system substantially as herein-
10 before described with reference to and as illustrated in Figure 1, 2 or 3 of the accompanying drawing.

11. A liquid lens having at least one flexible membrane supported by a suspension system as claimed in any one of the preceding claims.

15 12. A flexible membrane mirror in which the reflective membrane of the mirror is supported by a suspension system as claimed in any one of claims 1 to 9.
