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(54) **A discharge tube arrangement.**

(57) An electrodeless discharge tube (30, 40, 50, 60) containing an ionizable fill is provided for a discharge tube arrangement in which the discharge is generated and sustained using electromagnetic surface waves. The discharge tube comprises a first portion (32, 42, 52, 62) for insertion in a launcher. A further portion (36, 46, 54, 64) of the tube has a dissimilar cross-section from the cross-section of said first portion.

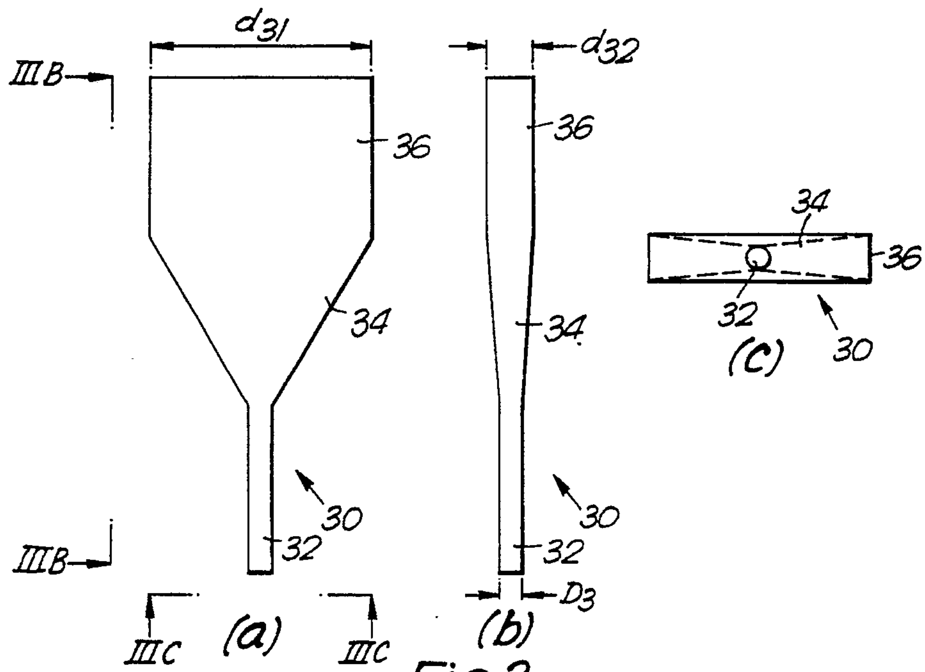


Fig.3.

EP 0 405 816 A2

A DISCHARGE TUBE ARRANGEMENT

This invention relates to a discharge tube arrangement and in particular, though not exclusively, to such an arrangement for use as a light source. In particular, this invention relates to a discharge tube for such a discharge tube arrangement.

It is known, e.g. as disclosed in EP 0225753A (University of California), to generate and sustain a discharge in a gas using electromagnetic surface waves. Surface waves are created by a launcher which is positioned around and external of, but not extending the whole length of, the discharge tube containing the gas. In such an arrangement, it is not necessary to provide electrodes inside the discharge tube. The power to generate the electromagnetic wave is provided by a radio frequency (r.f.) power generator.

EP 0225753A discloses two types of discharge tube. One type is cylindrical as in conventional discharge tube arrangements. The other type of tube is tapered with a reducing taper from the end connected to the energizer (ie launcher) to the opposite end. In this latter arrangement, as the surface wave energy is absorbed in the discharge tube as it travels from one end to the other, less energy is needed by each additional increment of tube length for a given amount of brightness at any location along the tube length since the tube diameter is smaller. Such a tube accordingly produces a uniform radiation output.

Another geometry of discharge tube is disclosed in Proceedings of the XVII International Conference Phenomena in Ionized Gases (Budapest, 1985) Contributed Pages, pages 712-4: Moisan et al "Large diameter overdense microwave plasmas'. At one end the tube is of a size that can be accommodated by a launcher. The diameter of the other end of the tube is large relative to the launcher dimensions. A conical transition section between the two ends serves as a waveguide of gradually changing propagation coefficient. Such a discharge tube provides a relatively large diameter plasma column.

According to the present invention, there is provided an electrodeless discharge tube containing an ionizable fill, said tube comprising a first portion for insertion in a launcher, said tube further comprising a further portion having a dissimilar cross-section from the cross-section of said first portion.

The inventors have surprisingly discovered that it is possible to sustain a surface wave discharge in a discharge tube in which one portion has a dissimilar cross-section from another so that the cross-section of the discharge tube changes not only in size but also in type. The dimensions of a transitional portion intermediate the first portion and the further portion are advantageously chosen so as to alleviate the problem of reflection of the surface wave from the wall of the tube. Discharge tubes provided in accordance with the present invention can be used to produce plasmas of a variety of geometries. Advantageously, the first portion of the discharge tube is of circular cross-section and so can be accommodated in conventional launchers.

Embodiments of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figures 1 and 2 show sectional views of discharge tube arrangements, incorporating electrodeless discharge tubes; and

Figures 3 to 6 show embodiments of electrodeless discharge tubes provided in accordance with the present invention

As shown in Figure 1, a discharge tube arrangement comprises a discharge tube 1 (shown in part) mounted in a launcher 2. The discharge tube 1 is formed of a light-transmissive, dielectric material, such as glass, and contains a fill 4 of a noble gas, such as argon and an ionizable material, such as mercury. The launcher 2 is made of an electrically conductive material, such as brass, and formed as a coaxial structure comprising an inner cylinder 6 and an outer cylinder 8. Dielectric material 9 is provided inside the launcher 2, inter alia to hold the inner cylinder 6 in position within the outer cylinder 8. A first plate 10, at one end of the outer cylinder, provides a first end wall for the launcher structure. At the other end of the outer cylinder 8, a second plate 11, integral with the outer cylinder 8, provides a second end wall. The inner cylinder 6 is shorter than the outer cylinder 8 and so positioned within the outer cylinder 8 as to define a first annular gap 12 and a second annular gap 13. Each of the first plate 10 and second plate 11 has an aperture for passage of the discharge tube 1. The outer cylinder 8, the first plate 10 and the second plate 11 form an unbroken electrically conductive path around, but not in electrical contact with, the inner cylinder 6 to provide an r.f. screening structure therearound.

Suitable dimensions for the launcher of Figure 1 are as follows:

Launcher length	7-20mm
Launcher diameter (outer cylinder 8 diameter)	25-35mm but depends on size of discharge tube 1.
Inner cylinder 6 length	3-18mm
Inner cylinder 6 diameter	13mm but depends on size of discharge tube 1.
Length of launching gap (first gap 12)	0.5 - 3mm
Length of second gap 13.	1-10mm.

The thickness of the electrically conductive material is of the order of millimetres, or less, depending on the method of construction used.

An r.f. power generator 14 (shown schematically) is electrically connected to the launcher 2 via a coaxial cable 15 and an impedance matching network 16 (shown schematically) consisting of capacitors 17 and inductors 18. The r.f. power generator 14, the impedance matching network 15, the coaxial cable 18 and the launcher 2 constitute an r.f. powered excitation device to energise the gas fill to produce a discharge.

When the r.f. power generator 14 is switched on, an oscillating electric field, having a frequency typically in the range of from 1MHz to 1GHz, is set up inside the launcher 2. At the first and second gaps 12, 13, this electric field is parallel to the longitudinal axis of the tubular portion of the discharge tube 1. If sufficient power is applied, the consequent electric field produced in the gas fill 4 is sufficient to ionise the mercury to create a discharge through which an electromagnetic surface wave may be propagated in a similar manner to the arrangement of EP 0225753A. Accordingly, the launcher 2 powered by the r.f. power generator 14 creates and sustains a discharge in the gas fill - the length and brightness of the discharge depending, inter alia, on the size of the discharge tube 1 and the power applied by the r.f. power generator 14. Such a discharge tube arrangement may therefore be used as a light source.

In the embodiment of Figure 1, the first gap 12 and the second gap 13 each extend axially from respective ends of the inner cylinder 6, respectively to the first plate 10 and second plate 11. As the discharge tube 1 extends from both ends of the launcher 2, both the first and the second gaps 12, 13 are effective as launching gaps to create a discharge. If the first and second gaps 12, 13 are the same size, this results in a relatively symmetric discharge.

Figure 2 shows a second embodiment of a discharge tube arrangement. The launcher 20 is formed as a coaxial structure in a similar manner to the launcher 2 of Figure 1 and accordingly like parts are designated by like reference numerals. No aperture is provided in the second plate 11 and accordingly a discharge tube 22 (shown in part) extends from one side of the launcher 20 only. When power is supplied, the second gap 13 complements the effect of the first gap 12, which, as the launching gap, creates the discharge. The second gap 13 is, in this embodiment, advantageously larger than the launching gap 12. As with the embodiment of Figure 1, the r.f. power at the second gap 13 is dissipated in the discharge and not lost from the system as in prior art launchers.

Examples of electrodeless discharge tubes provided in accordance with the present invention and which can be used with the discharge tube arrangements of Figures 1 and 2 are shown in Figures 3, 4, 5 and 6.

Figure 3a is a plan view of an electrodeless discharge tube 30 and Figures 3b and 3c are views of the discharge tube 30 of Figure 3a looking in the directions IIIB-IIIB and IIIC-IIIC respectively. As can be seen, the discharge tube 30 comprises a first portion 32 of circular cross-section, and an intermediate portion 34 tapering into a further portion 36 of rectangular cross-section.

The dimensions, d_{31}, d_{32} of the further portion 36 transverse to the axis of the cylindrical portion 32 are greater than the diameter D_3, i.e. the transverse dimension, of the cylindrical portion 32. The further portion 36 presents a rectangular surface.

Similarily, Figure 4a is a plan view of an electrodeless discharge tube 40 and Figures 4b, 4c and 4d are views of the discharge tube 40 of Figure 4a looking in the directions IVB-IVB, IVC-IVC and IVD-IVD respectively. The discharge tube 40 comprises a first portion 42 of circular cross-section, an intermediate portion 44 and a further portion 46 of rectangular cross-section which presents a rectangular surface. The maximum dimension d_{41} of the further portion 46 transverse to the axis of the cylindrical portion 42 is greater than the diameter D_4 of the cylindrical portion 42. The minimum transverse dimension d_{42} of the further portion 46 is orthogonal to its maximum dimension d_{41} and is less than the diameter D_4 of the cylindrical portion 42.

Discharge tube arrangements incorporating the electrodeless discharge tubes of Figures 3 and 4 can be used in a variety of applications. Examples include providing backlighting as a large planar light source or creating a uniform plasma over a large surface for non-lighting applications such as plasma coating/etching etc.

Figure 5a is a plan view of an electrodeless discharge tube 50 and Figures 5b and 5c are views of the discharge tube 50 of Figure 5a looking in the directions VB-VB and VC-VC, respectively. The discharge tube 50 comprises a first portion 52 of circular cross-section and a further portion 54 which presents a triangular surface. The maximum transverse dimension d_{51} of the triangular portion 54 is greater than the diameter D_5 of the cylindrical portion 52. A discharge tube arrangement incorporating such a discharge tube can be used in a variety of applications. One example is to provide a thin strip of light of width d_{52} from the face 56 of the discharge tube 50.

Figure 6a is a sectional view of an electrodeless discharge tube 60 and Figure 6b is a view of the discharge tube 60 looking in the direction VIB-VIB. The discharge tube 60 comprises a first portion 62 of circular cross-section and a further portion 64 having an annular cross-section presenting an annular face 66.

From the embodiments of electrodeless discharge tubes illustrated, it can be seen that a wide variety of shapes of discharge tubes can be provided by the present invention. As well as providing light sources of required shapes for specific applications, the present invention also provides the potential for creating light sources of many interesting shapes for interior design etc.

It is also envisaged that discharge tube arrangements incorporating the launcher of Figure 1 can be fitted with electrodeless discharge tubes in which a further portion of a required shape extends from each end of the portion of circular cross-section.

The discharge tube arrangement may be provided with a helical wire wound around the discharge tube. The helical wire is earthed and extends along the discharge tube. Such a structure increases the light output of the discharge tube arrangement and provides some r.f. screening as disclosed in copending European Patent Application No. 89313069.0.

The embodiments illustrated have all been described with first portions of circular cross-section for insertion into a launcher with a structure incorporating an inner cylinder as described with relation to Figures 1 and 2. If a launcher of another configuration is used, then this should be used with electrodeless discharge tubes having a first portion so shaped as to fit inside the inner body of the launcher.

Other modifications to the embodiments described herein and within the scope of the present invention will be apparent to those skilled in the art.

Claims

1. An electrodeless discharge tube containing an ionizable fill, said tube comprising a first portion for insertion in a launcher, said tube further comprising a further portion having a dissimilar cross-section from the cross-section of said first portion.
2. A discharge tube according to Claim 1 wherein said first portion is of circular cross-section.
3. A discharge tube according to Claims 1 or 2 wherein said first portion is at one end of said tube.
4. A discharge tube according to Claims 1 or 2 wherein a said further portion extends from each end of said first portion.
5. A discharge tube according to any one of the preceding claims wherein said further portion has a maximum transverse dimension greater than the maximum transverse dimension of said first portion.
6. A discharge tube according to any one of the the preceding claims wherein said further portion has a minimum transverse dimension which is less than the maximum transverse dimension of said first portion.
7. A discharge tube according to Claim 6 wherein said minimum transverse dimension of said further portion is orthogonal to said maximum transverse dimension of said further portion.
8. A discharge tube according to any one of the preceding claims wherein said further portion presents a triangular surface.
9. A discharge tube according to any one of Claims 1 to 8 wherein said further portion presents a rectangular surface.
10. A discharge tube according to any one of Claims 1 to 6 wherein said further portion has an annular cross-section.
11. A discharge tube according to Claim 10 wherein said further portion is frustoconical.
12. A discharge tube arrangement comprising a launcher, an r.f. power generator for energising said launcher and an electrodeless discharge tube according to any one of the preceding claims.

Fig.1.

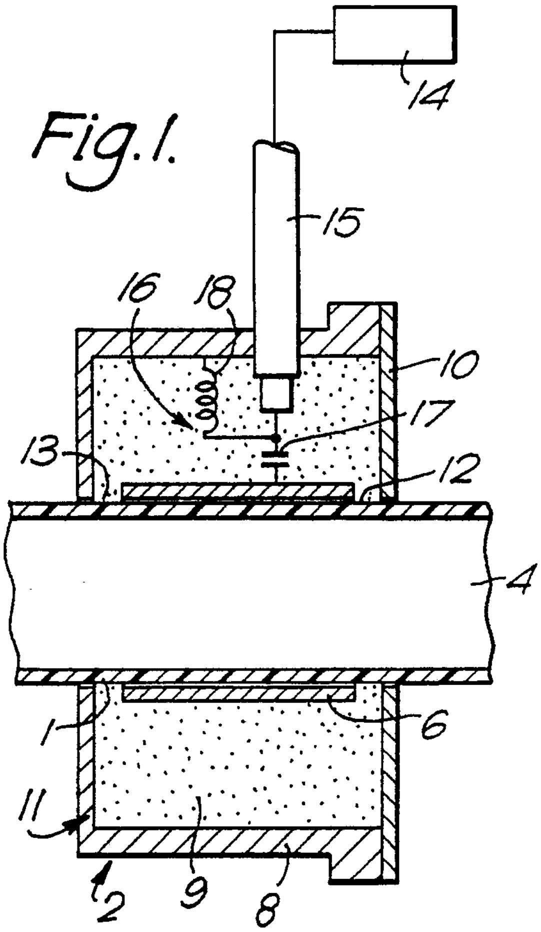
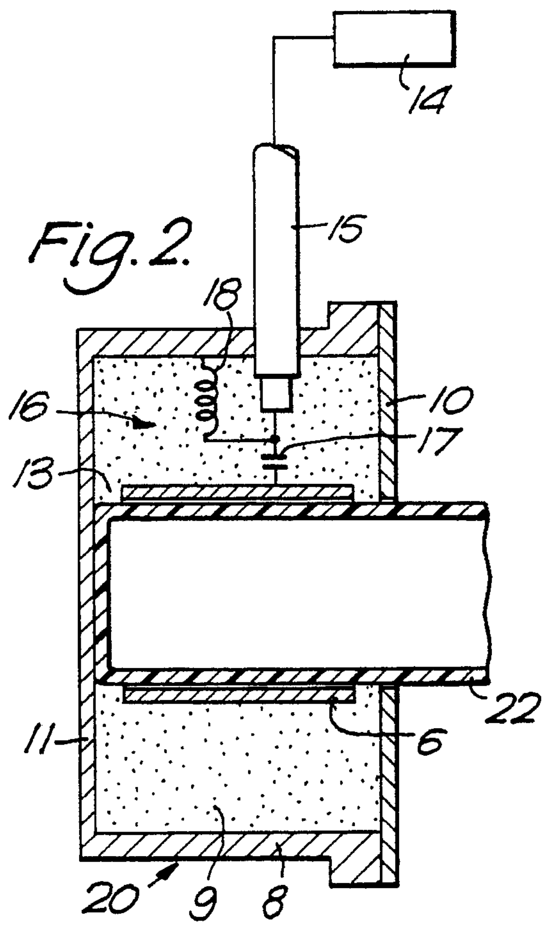


Fig.2.



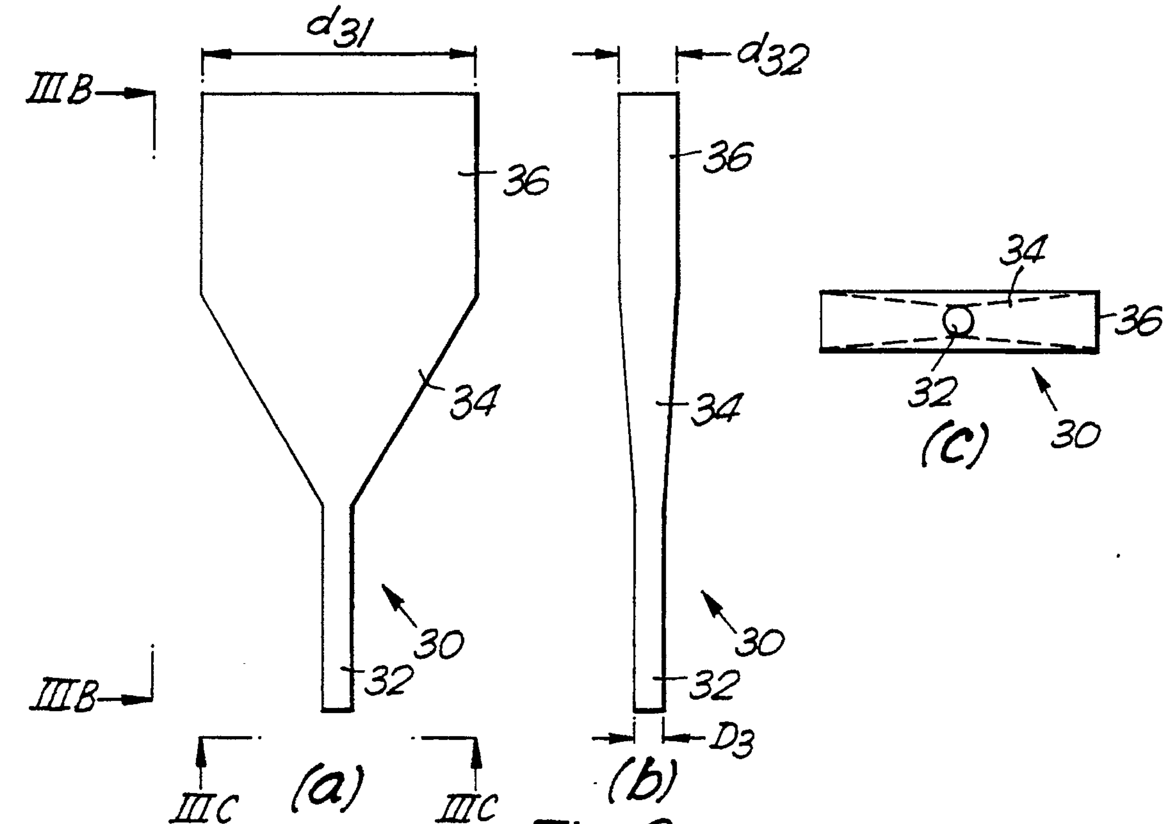

d31
d32
IIIB
36
34
30
32
D3
IIIC
(a)
(b)
(c)

Fig.3.

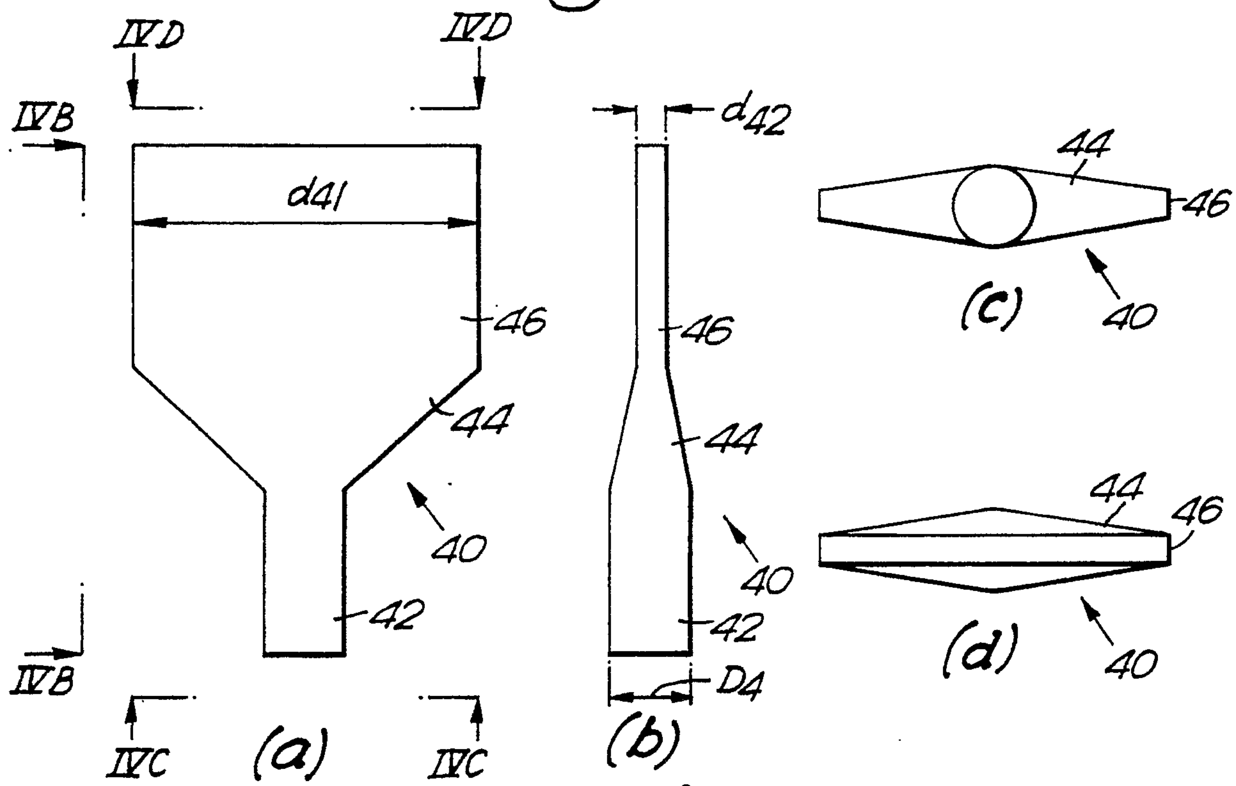

IVD
IVB
d41
d42
46
44
40
42
D4
IVC
(a)
(b)
(c)
(d)

Fig.4.

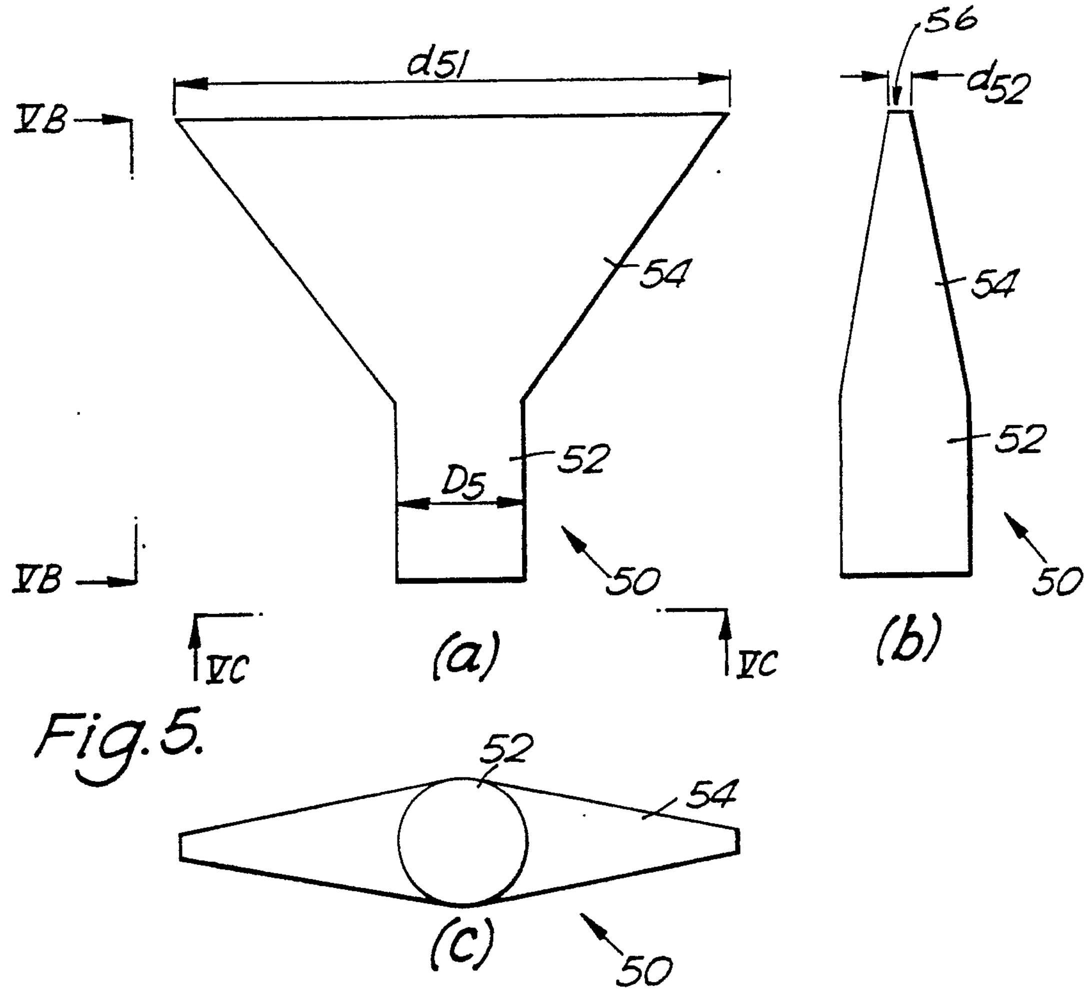

56
d51
d52
VB
54
54
52
52
D5
VB
50
50
VC
(a)
VC
(b)
52
54
(c)
50

Fig.5.

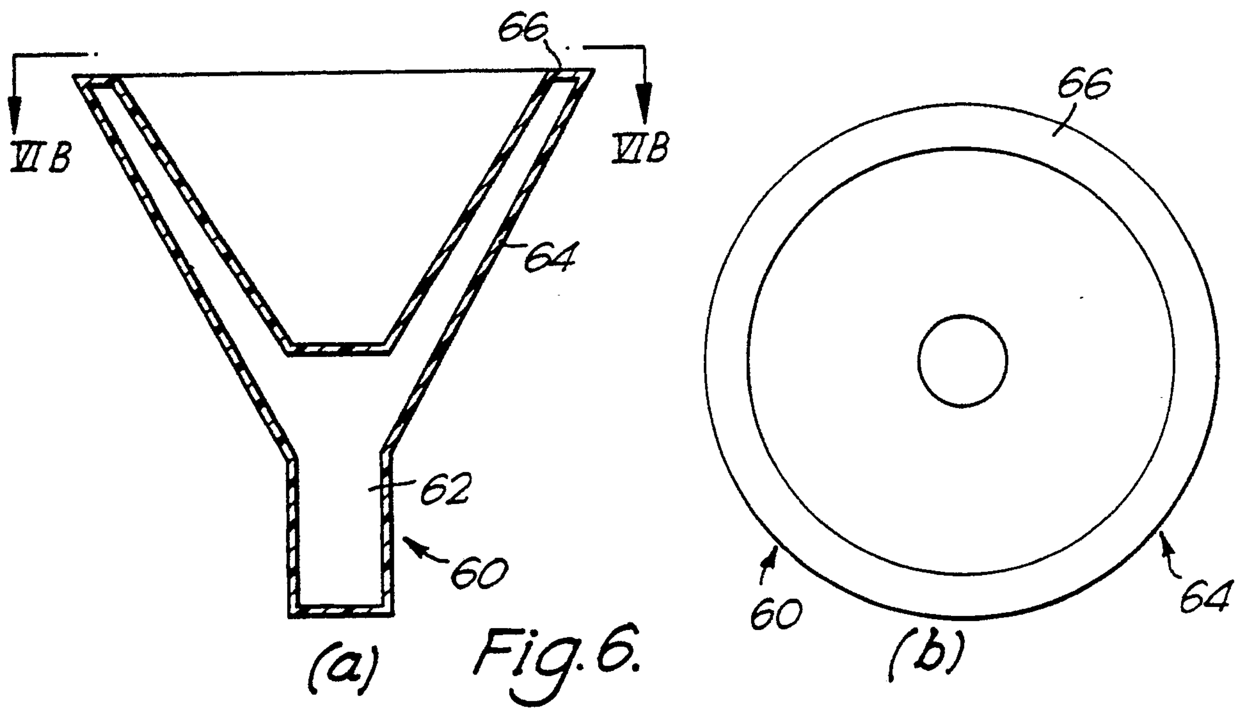

66
66
VIB
VIB
64
62
60
60
64
(a)
(b)

Fig.6.