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## (54) Discharge arc lamp.

(57) A discharge arc lamp includes an arc tube (1) containing a dose, an electrode structure (4) sealed to each end of the arc tube, and an insert member (11; 23, 24) positioned between the arc tube wall and at least one said electrode structure(4). The insert member (11; 23, 24) is arranged to define a wick (12, 13, 15; 22, 22′; 25, 25′) which is effective, in operation of the lamp, to more liquid dose, by capillary action, from a relatively cold region ($R_1$) of the arc tube (1) adjacent to said end into a reservoir ($R_2$) in a relatively hot region of the arc tube (1), and to further define a passageway (16) allowing movement of dose, by vapour diffusion, to said relatively cold region ($R_1$). The wick (12, 13, 15; 22, 22′; 25, 25′) is so configured as to accommodate a variable volume of liquid dose. The passageway is configured to enable attainment of a desired operating pressure in the arc tube (1). The distributions of vapour pressure and temperature along the passageway encourage condensation of vapour at said relatively cold region ($R_1$) such that the wick (12, 13, 15; 22, 22′; 25, 25′) can maintain a substantially continuous supply of liquid dose at the reservoir ($R_2$). Such a discharge arc lamp has an effective cool spot temperature, at the exposed surface of liquid in the reservoir ($R_2$) supplied by the wick (12, 13, 15; 22, 22′; 25, 25′), which is higher than the temperature at the ends of the arc tube (1).

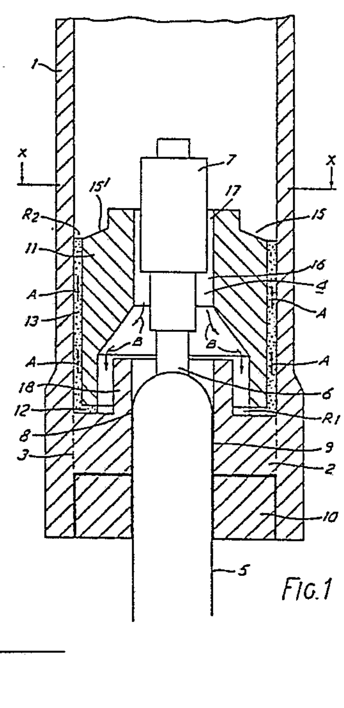


FIG.1

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**Description**

## DISCHARGE ARC LAMP

This invention relates to a discharge arc lamp and it relates particularly, though not exclusively, to a high pressure sodium discharge arc lamp.

A known high pressure sodium discharge arc lamp, marketed by the Applicant company under the trade name SONDL, operates at a relatively high colour temperature (2150K) with a desirable colour rendering index, typically $R_a = 65$ .

The SONDL operates at a relatively high vapour pressure requiring a high cool spot temperature. In the SONDL, this is achieved by provision of a heat shield around each end of the discharge arc tube near to a respective discharge electrode. In practice, it is found that the cool spot temperature depends critically on the length of heat shield used and on the size of a back-space between a discharge electrode and an adjacent end of the arc tube. The tolerancing required in manufacture, therefore, can be extremely exacting, leading to increased production costs. Furthermore, during lamp operation, variations in operating conditions such as lamp voltage, supply voltage and choke impedance may give rise to small yet significant fluctuations of lamp power. At the relatively high cool spot temperatures needed in the SONDL, the glassy sealing material used to seal the discharge electrodes to the ends of the arc tube can chemically combine with sodium in the lamp dose and increases of lamp power tend to exacerbate the problem. Progressively, over a period, sodium is removed from the dose reducing the Na mole fraction (nominally 0.744 in the case of the SONDL) in the arc tube and causing a gradual increase of lamp voltage, which eventually causes the lamp to cycle on and off and limits its useful life. Also, the colour of light emitted by the lamp changes, becoming pinker through life.

It is an object of the present invention to provide a different form of discharge arc lamp construction which, in the case of a high pressure sodium discharge arc lamp, at least alleviates the problems described.

According to a first aspect of the invention there is provided a discharge arc lamp including an arc tube containing a dose, an electrode structure sealed to each end of the arc tube, and an insert member positioned between the arc tube wall and at least one said electrode structure wherein said insert member is arranged to define a wick which is effective, in operation of the lamp, to move liquid dose, by capillary action, from a relatively cold region of the arc tube adjacent to said end into a reservoir in a relatively hot region of the arc tube, and to further define a passageway allowing movement of dose, by vapour diffusion, to said relatively cold region, said wick being so configured as to accommodate a variable volume of liquid dose and said passageway being configured to enable attainment of a desired operating pressure in the arc tube, the distributions of vapour pressure and temperature along the passageway encouraging condensation of vapour at said relatively cold region such that the wick can maintain a substantially continuous supply of liquid dose at the reservoir.

A stable operating pressure is established, and maintained, in the arc tube by evaporation of liquid dose from said substantially continuous supply held in the reservoir, and the effective cool spot temperature of the lamp, at the surface of liquid in the reservoir, is significantly higher than the temperature at said end of the arc tube, where the electrode seal is located. Therefore, in the case of a high pressure sodium discharge arc lamp, the relatively cold seal material is less likely to combine chemically with sodium in the lamp dose giving a more stable lamp operation and longer lamp life. Moreover, the need for a specific heat shield, with its attendant tolerancing problems, is eliminated. Since the movement of dose is controlled by capillary action and by vapour diffusion the lamp can operate satisfactorily in any desired orientation, unlike other, hithertoknown forms of wick lamp.

Said passageway may be located around said electrode structure and may have a constricted inlet enabling the operating vapour pressure in the arc tube to be of the same order as the vapour pressure immediately above the surface of the reservoir. Preferably, the cross-sectional area presented by the constricted inlet may be the same as, or similar to, the area of exposed surface of liquid dose held in said reservoir. In general, the ratio of the area of the exposed surface of dose to the cross-sectional area presented by the inlet should be greater than about 1/10, and preferably greater than 1/2, and can be as large as is practically possible.

In order to accommodate a variable volume of liquid dose the wick may have a transverse cross-section of non-uniform width and, in particular, may be defined by adjacent, curved sides. The wick may have oppositely curved sides and, in an example, may have a generally lens-shaped cross-section defined by an inner surface of the arc tube wall and by the surface of a longitudinal channel formed in the insert member. The insert member may be arranged to define a plurality of wicks each having a longitudinally-extending part, and said reservoir may comprise an annular channel which is adapted to transfer dose, by capillary action, into the reservoir. Each wick may also have a radially-extending part which connects the respective longitudinally extending part to said relatively cold region of the arc tube. In order that the effective cool spot temperature of the lamp may be substantially independent of volume changes in the reservoir, the reservoir may be adapted to maintain therein a substantially constant level of liquid dose. Said transfer of dose and said maintenance of a substantially constant level may be accomplished by provision of a said channel having a sloping side wall.

A wall may be provided around the electrode structure in the vicinity of the seal. The wall prevents excess sealing material blocking the entrances to the wicks during lamp assembly and also promotes condensation of dose in said relatively cold region of the arc tube near the entrances to the wicks.

It will be appreciated that although the present invention has specific application to a high pressure sodium discharge arc lamp the invention has wider applicability to discharge arc lamps generally, including sodium, mercury and metal halide discharge arc lamps.

In accordance with another aspect of the invention there is provided an insert member suitable for use in the arc tube of a discharge arc lamp according to said first aspect of the invention.

In order that the invention may be carried readily into effect an embodiment thereof is now described, by way of example only, by reference to the accompanying drawings of which

Figure 1 shows a longitudinal, cross-sectional view through one end of a high pressure sodium discharge arc lamp,

Figure 2 shows a transverse, cross-sectional view of the lamp taken on line X-X in Figure 1,

Figure 3 illustrates qualitativity the distributions of vapour pressure and temperature along a passageway in the lamp construction of Figures 1 and 2 and

Figure 4 illustrates, on an enlarged scale, a region identified at W in Figure 2.

Figure 5 shows a longitudinal cross-sectional view showing the detail on line Y-Y in Figure 1.

Figure 6 shows a transverse, cross-sectional view through a discharge arc lamp having a differently configured insert member,

Figure 7 shows a longitudinal, cross-sectional view through one end of a further, differently configured discharge arc lamp and Figure 8 shows a transverse, cross-sectional view taken on line ZZ in Figure 7.

Figure 1 of the drawings shows a cross-section view through one end of a high pressure sodium discharge arc lamp, the other end being substantially identical.

The lamp comprises an arc tube 1 made of a light-transmissive ceramic material, e.g. polycrystalline alumina, fitted with a ceramic end plug 2 which is sintered to the arc tube wall (represented diagrammatically by broken line 3) to form a monolithic structure.

The end plug supports an electrode structure shown at 4 in side elevation. The electrode structure comprises a tubular lead-in member 5 (also shown in side elevation), made of niobium for example, and an electrode shank 6 which is mounted on the lead-in member and supports an over-wound electrode assembly 7 which may be impregnated with an emissive material. Both the electrode shank and the electrode assembly could be made of tungsten for example.

The tubular lead-in member 5 extends through a central hole 8 in the end plug and is sealed therein by means of a glassy sealing material (layer 9), and it is this sealing material which can chemically combine with sodium in the arc tube resulting in a loss of sodium from the dose. The end closure is completed by provision of an end cap 10 which fills an annular space between the arc tube wall and the lead-in member.

A different form of electrode structure could alternatively be used; for example, a lead-in member and an electrode-supporting shank set individually into a cermet end cap. Clearly, other forms of end closure can be envisaged.

Referring now to Figures 1 and 2, the arc tube also includes a generally tubular insert member 11 which surrounds the electrode structure 4, as best seen in the end-on view of Figure 2. The insert member, which is made of a ceramic material (STELLOX (RTM) in this example) and is sintered to the arc tube wall, has a plurality of channels each comprising two parts; a radially-extending part 12 formed in an outer end surface of the insert member and a longitudinally-extending part 13 formed in a side surface 14. In this example the insert member has four such channels spaced at regular intervals around the electrode structure, though an alternative number of channels could be provided. For reasons which will become apparent hereinafter, each channel formed in the insert member has a part-circular cross-section.

The insert member is conveniently formed by pressing, though alternative processing techniques e.g. machining or extruding could be used.

Each channel, in association with adjacent surfaces of the arc tube wall and end plug, defines a wick, having a longitudinally and a radially extending part, which is effective during operation of the lamp to move liquid dose, by capillary action, from a region $R_1$ in a relatively cold part of the arc tube, adjacent to the end plug and the electrode seal, to a reservoir $R_2$ located in a relatively hot part of the arc tube closer to the discharge arc.

Reservoir $R_2$ comprises a generally annular channel 15 defined by an internal surface of the arc tube wall and by an inwardly sloping surface 15′ formed at the inner end of the insert member, as illustrated in the longitudinal, sectional view of Figure 5. The longitudinally extending part of each wick opens into reservoir $R_2$, and since channel 15 has a generally tapered cross-section it is effective as an additional wick to transfer dose, by capillary action, into, and along, the reservoir. Also, as will be described in greater detail hereafter the sloping side wall serves to maintain the level of liquid dose in the reservoir substantially constant.

A central hole 16 in the insert member defines a passageway around the electrode structure which extends from the inner to the outer end surface. The passageway has a constricted inlet opening 17 and is wider at its outer end, adjacent to region $R_1$.

During operation of the lamp, vapour evaporates from, and condenses at, the exposed surface S of liquid held in reservoir $R_2$. The cross-sectional area of inlet opening 17 is made sufficiently small so as to ensure that the operating pressure in the arc tube is of the same order as the vapour pressure immediately above surface S, corresponding to the effective cool spot temperature at surface S. In an example, the cross-sectional area presented by the inlet opening approximately equals the area of exposed surface S.

Each wick is effective to transfer liquid, by capillary action, from region $R_1$ to reservoir $R_2$, as represented by arrows A in Figure 1, and dose is returned to region $R_1$, by vapour diffusion, as represented by arrows B. Liquid is otherwise retained in the reservoir by the effect of surface tension, and so the lamp can operate in any desired orientation. The supply of dose held in reservoir $R_2$ should be maintained continually and, in order to promote a satisfactory circulation of dose, the distributions of temperature and vapour pressure along the passageway, illustrated qualitatively in Figure 3, are so tailored as to encourage vapour to condense in region $R_1$, whilst allowing a desired lamp operating pressure in the main body of the arc tube to be achieved. To this end, vapour pressure in the passageway falls off rapidly in the direction approaching region $R_1$, due to the constriction in the inlet 17. The temperature, however, is held relatively high along a substantial part of the passageway, this being achieved by the close proximity of the ceramic insert member 11 to the hot electrode structure 4. This, in combination with the pressure distribution, tends to inhibit condensation of dose on the sides of the passageway.

In addition, end plug 2 is configured to provide a short tubular wall 18 around the lead-in member 5. This wall prevents excess sealing material blocking the entrances to the wicks during lamp assembly and also promotes condensation of dose in region $R_1$.

The operating pressure in the arc tube does, of course, depend on the effective cool spot temperature at the exposed surface S of liquid in reservoir $R_2$ which, in turn, depends on the level of liquid in the reservoir i.e. the proximity of surface S to the discharge arc. The inwardly sloping surface 15′ of channel 15 serves to reduce the effect of any volume change in the reservoir and thereby maintain the exposed surface S at a substantially constant level (and so cool spot temperature).

Particularly during lamp run-up, the dose may not be distributed evenly between the ends of the arc tube and so each wick should be capable of transferring a variable volume of liquid without interruption. To that end, each wick in this example of the invention, has a generally lens-shaped, transverse cross-section, as is best seen in Figure 4 which illustrates, on an enlarged scale, a region identified at W in Figure 2.

The oppositely curved sides 19, 20 of each lens-shaped wick are defined respectively by the surface of a channel 13, formed in the insert member, and by an inner surface of the arc tube wall. With a configuration of this kind, relatively small volumes of liquid occupy the narrow, edge regions E of the wick, as shown, and larger volumes occupy more of the central region C. In a typical example the lens shape might have a width w of 2.2 mm, and a breadth b of 0.4 mm, the radii of curvature of sides 19, 20 being 3.0 mm and 3.7 mm respectively.

Figures 6 to 8 of the drawings illustrate two alternative forms of wick configuration and where a component corresponds to that used in the configuration of Figure 1 it has been ascribed a like reference numeral. Referring initially to Figure 6, the insert member 11 includes four elongate parts 21 each having a convex, transverse cross-section and making contact with the arc tube wall thereby defining respective pairs of wicks (e.g. 22, 22′). Figures 7 and 8 show an arrangement wherein the insert member is in two parts. An upper part 23 which has four substantially lens-shaped wicks, is similar to that shown in Figures 1, 2, 4 and 5 and a lower part consists of four cylindrical rods 24 which are aligned with the lens-shaped wicks of the upper part and make line contact with the arc tube, again defining respective pairs of wicks 25, 25′ (Figure 8).

Other wick constructions will be apparent to those skilled in the art; it will be understood, for example, that any other way of configuring the inner surface of the arc tube wall and or the outer surface of the insert member which achieves a wicking action falls within the scope of the present invention.

A discharge arc lamp in accordance with this invention has an effective cool spot temperature, at the exposed surface of liquid in the reservoir supplied by the wick, which is higher than the temperature at the ends of the arc tube and in the case of a hgh pressure sodium discharge arc lamp it is possible to achieve the relatively high operating pressure, as used in the SONDL lamp for example, but at a much lower seal temperature. The rate of chemical reaction between the glassy sealing material and sodium in the lamp dose is much reduced resulting in a lower rate of rise of lamp voltage through life, leading to longer life, and a reduction of colour change through life. Moreover, the need for a heat shield, of the kind used in the SONDL lamp, is eliminated and the tolerancing associated with positioning the insert member in the arc tube is far less exacting than that associated with manufacture and assembly of discharge arc lamp configurations known hitherto. In addition, hitherto known lamps suffer from blackening at the ends of the arc tubes due to emitter material being thrown off by the electrode assembly and this tends to cause an undesirable increase in cool spot temperature giving rise to a change of lamp voltage and colour through life, in addition to the effect caused by sodium loss. In the present invention the insert member tends to prevent blackening in the region of the reservoir $R_2$, i.e. the effective cool spot, thereby reducing variation of both voltage and colour.

It will be understood that although the present invention has specific application to a high pressure sodium discharge arc lamp, particularly a high pressure sodium discharge arc lamp operating at the relatively high vapour pressures used in the SONDL lamp, the invention has wider applicability to discharge arc lamps generally, including sodium, mercury and metal halide lamps.

It is believed that a discharge arc lamp in accordance with the present invention can, by use of an insert member as defined, attain a higher cool spot temperature (and so vapour pressure) than could, in general, be attained using a hitherto known, commercially acceptable, lamp construction, thereby giving considerable scope for improved lamp design.

For example, a higher effective cool spot temperature could permit a reduction in the mercury content of the dose giving an improved voltage/power characteristic. Alternatively, a higher cool spot temperature could be used to achieve a relatively high colour rendering index, and it is believed, for example, that a colour rendering index in excess of 80 can be achieved in a high pressure sodium discharge lamp having an efficacy of between 40 and 45 lm/watt.

Furthermore it is believed that a higher cool spot temperature may allow use of metals and metal halides in the dose which, on account of their low volatility, would be unsuitable for use in lamps of hitherto known construction.

## Claims

1. A discharge arc lamp including an arc tube containing a dose, an electrode structure sealed to each end of the arc tube, and an insert member positioned between the arc tube wall and at least one said electrode structure wherein said insert member is arranged to define a wick which is effective, in operation of the lamp, to move liquid dose, by capillary action, from a relatively cold region of the arc tube adjacent to said end into a reservoir in a relatively hot region of the arc tube, and to further define a passageway allowing movement of dose, by vapour diffusion, to said relatively cold region, said wick being so configured as to accommodate a variable volume of liquid dose and said passageway being configured to enable attainment of a desired operating pressure in the arc tube, the distributions of vapour pressure and temperature along the passageway encouraging condensation of vapour at said relatively cold region such that the wick can maintain a substantially continuous supply of liquid dose at the reservoir.

2. A discharge arc lamp according to Claim 1 wherein said passageway is located around said electrode structure and has a constricted inlet enabling the operating vapour pressure in the arc tube to be of the same order as the vapour pressure immediately above the surface of the reservoir.

3. A discharge arc lamp according to Claim 2 wherein the cross-sectional area of said constricted inlet is the same as, or similar to, the area of the exposed surface of liquid dose held in said reservoir.

4. A discharge arc lamp according to any one of Claims 1 to 3 wherein said wick has a transverse cross-section of non-uniform width.

5. A discharge arc lamp according to Claim 4 wherein said wick has a generally lens-shaped cross-section defined by an inner surface of the arc tube wall and by the surface of a longitudinal channel formed in the insert member.

6. A discharge arc lamp according to any one of Claims 1 to 5 wherein the insert member is arranged to define a plurality of wicks, each having a longitudinally-extending part, and said reservoir comprises an annular channel which is adapted to transfer dose, by capillary action, into the reservoir.

7. A discharge arc lamp according to any one of Claims 1 to 6 wherein said reservoir is adapted to maintain therein a substantially constant level of liquid dose.

8. A discharge arc lamp according to Claim 6 and Claim 7 wherein said annular channel has a sloping side wall thereby to effect said transfer and maintain said substantially constant level.

9. A discharge arc lamp according to any one of Claims 6 to 8 wherein each one of said plurality of wicks has a radially-extending part which connects the respective longitudinally-extending part to said relatively cold region of the arc tube.

10. A discharge arc lamp according to any one of Claims 1 to 9 including a barrier around the electrode structure.

11. A ceramic discharge arc lamp according to any one of Claims 1 to 10.

12. A high pressure sodium discharge arc lamp according to any one of Claims 1 to 11.

13. An insert member suitable for use in the arc tube of a discharge arc lamp according to any one of Claims 1 to 12.

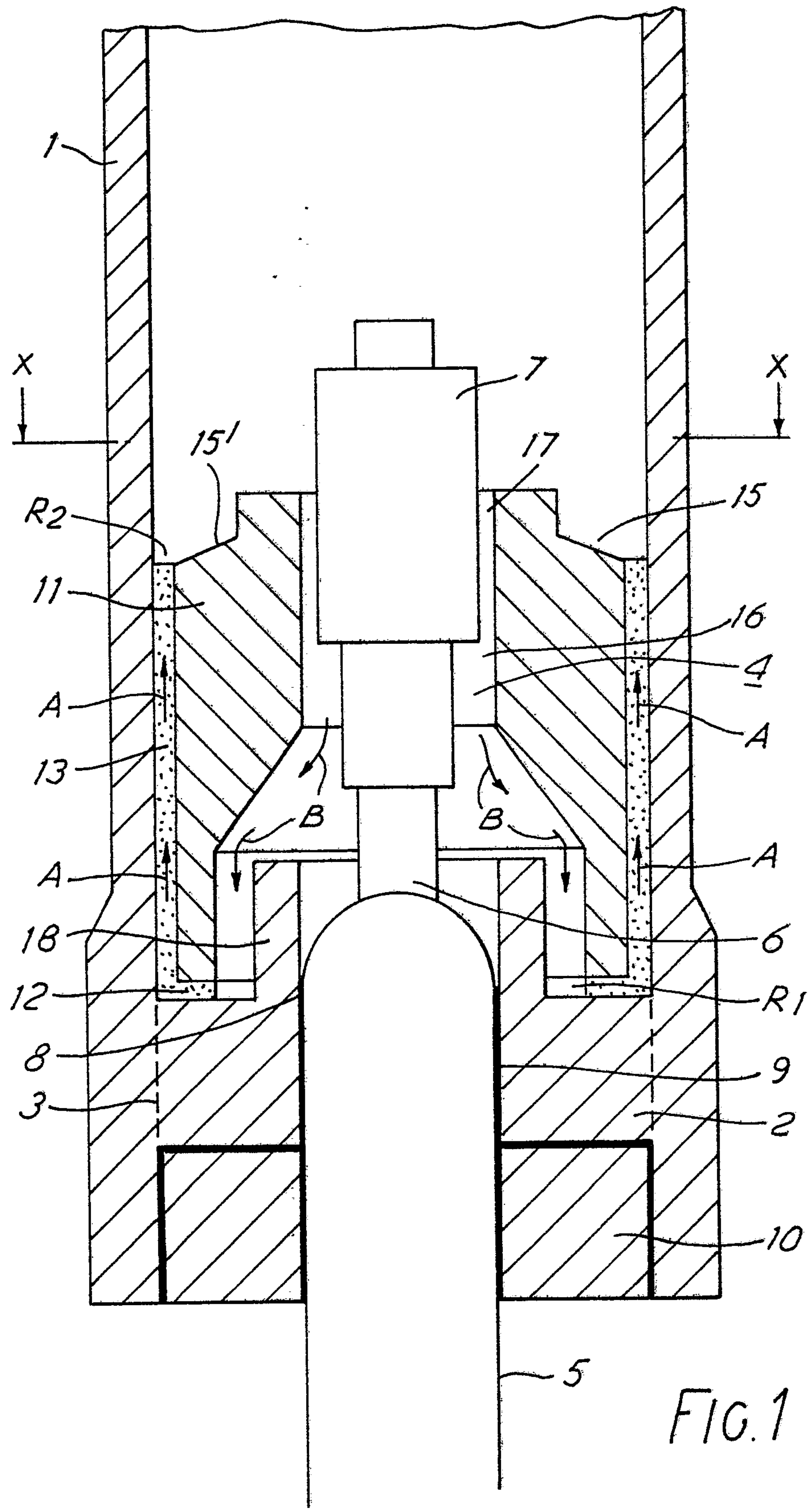


FIG.1

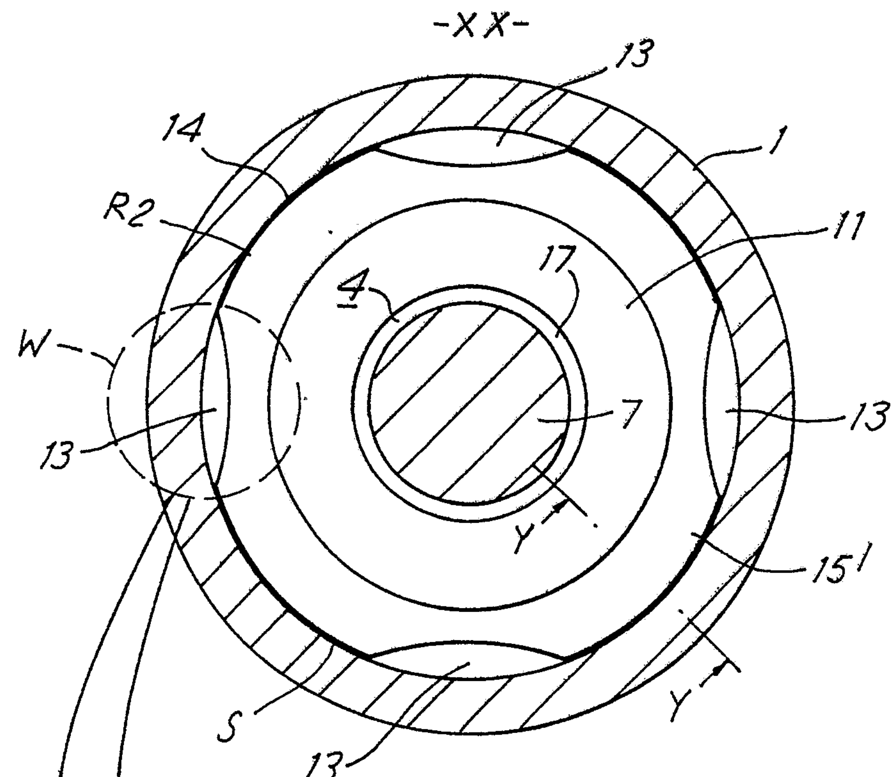


FIG.2

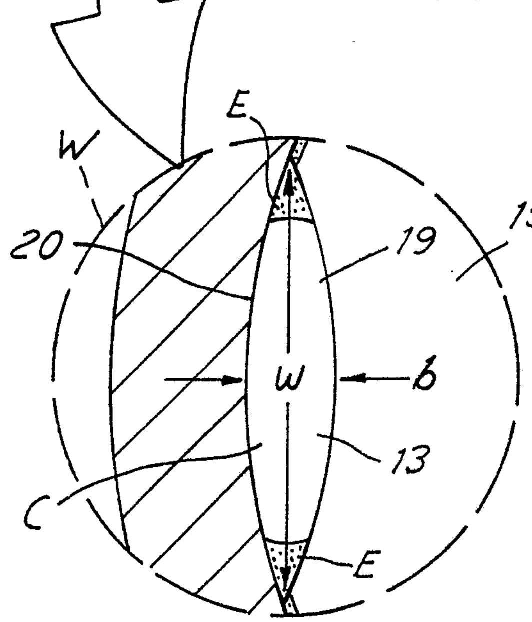


FIG.4

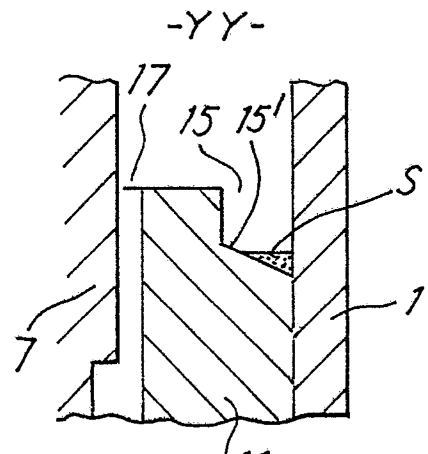


FIG.5

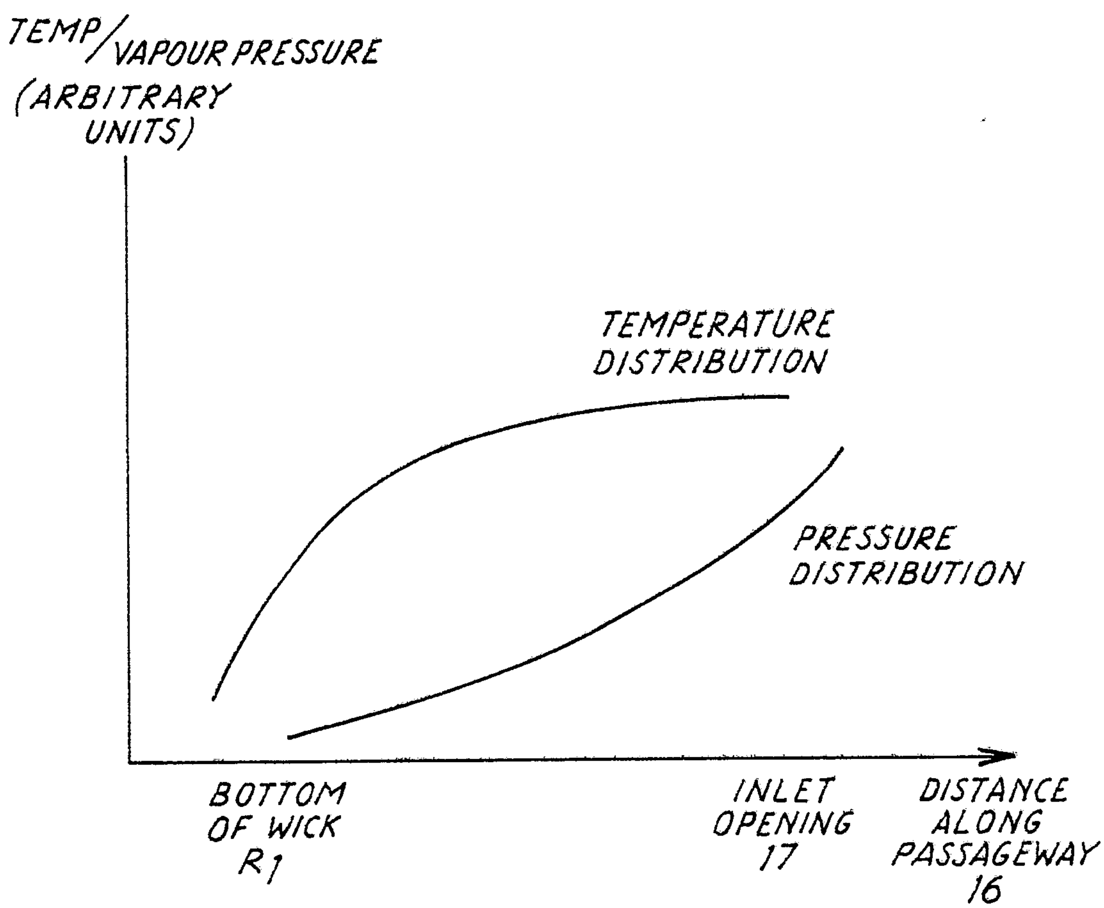
TEMP/VAPOUR PRESSURE
(ARBITRARY UNITS)
TEMPERATURE DISTRIBUTION
PRESSURE DISTRIBUTION
BOTTOM OF WICK R1
INLET OPENING 17
DISTANCE ALONG PASSAGEWAY 16

FIG. 3

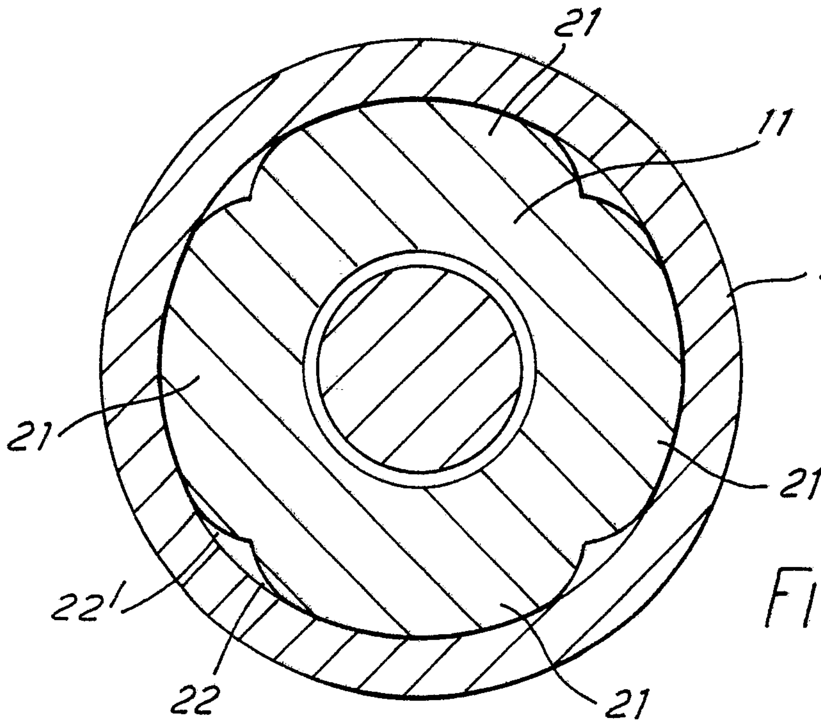


FIG. 6

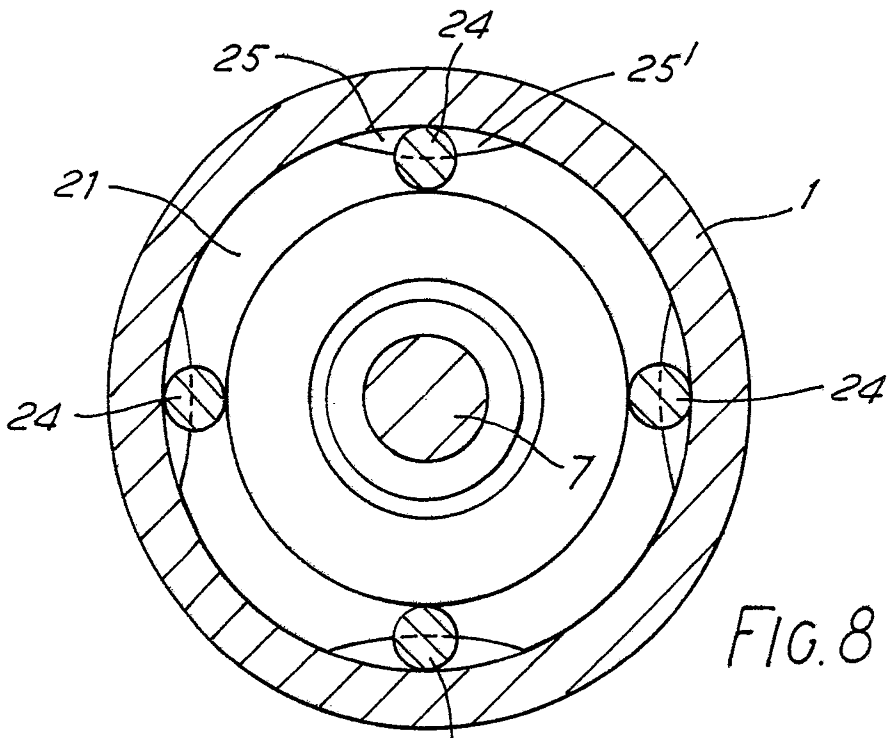


FIG. 8

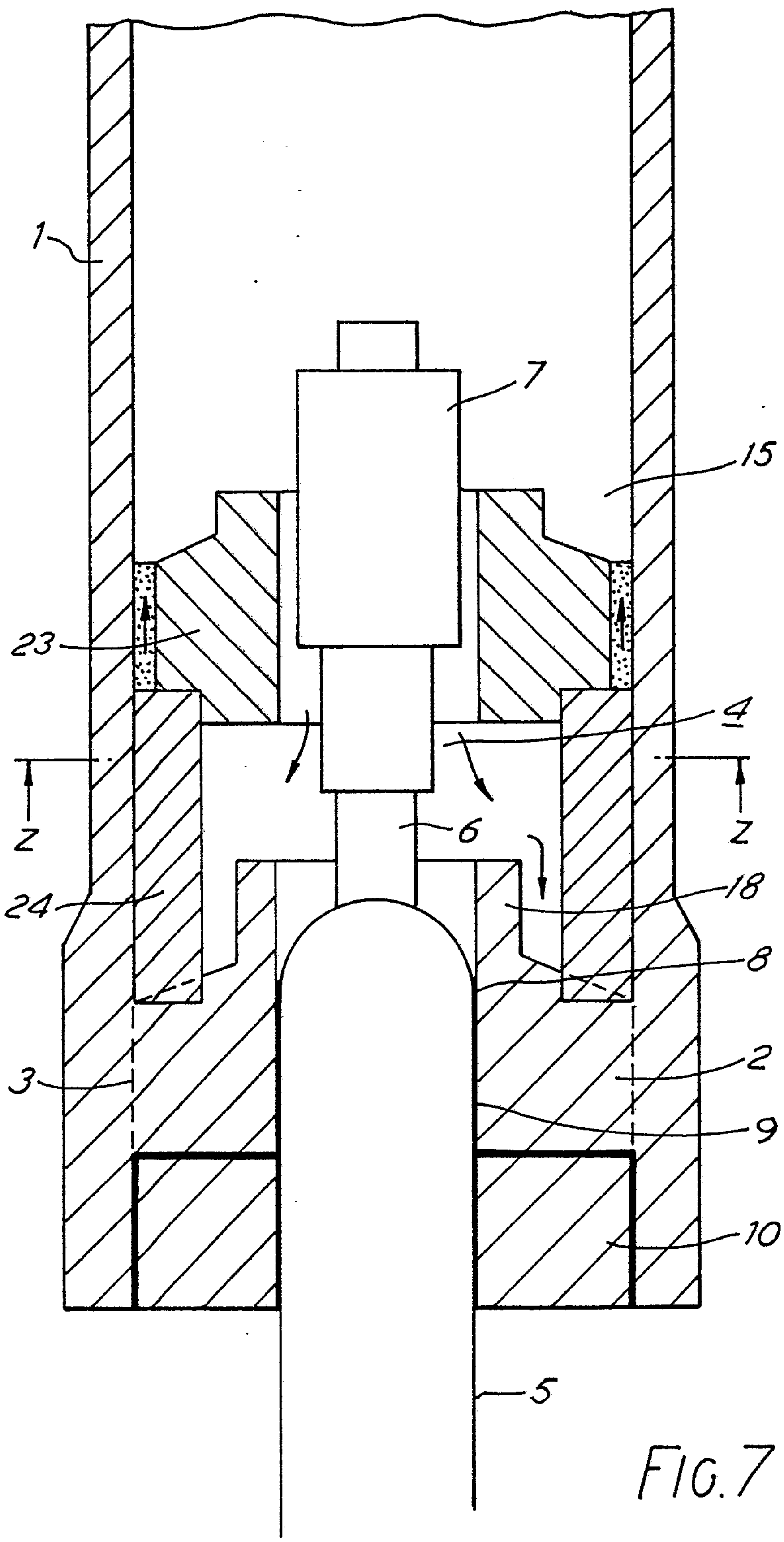


FIG.7