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## (54) Cavitation-resistant inducer.

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**DE-A- 2 116 091**
**US-A- 3 163 119**
**US-A- 3 697 190**
**GB-A- 684 230**
**US-A- 3 442 220**
**US-A- 3 751 178**

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## Description

### Background of the Invention

#### 1. Field of the Invention

The present invention relates to an inducer (for axial and centrifugal pumps) in accordance with the preamble of the main claim. Such an inducer is known from DE-A-2 116 091 and GB-A-684 230. The present invention provides an inducer capable of operating over a wider range of flow rates with less risk of cavitation and a higher efficiency than would otherwise be possible.

#### 2. Description of the Prior Art

In general when a pump is required to operate over a wide range of flow capacities and has an optimum rate of fluid in flow which takes place at the design duty point, the parts of the pump may undergo extensive wear resulting from cavitation whenever the pump is operated in a part-load flow region. The effects of cavitation are more pronounced in larger pumps and the wear owing to cavitation also increases with increasing rotational speed. Attempts to reduce the wear which is attributal to cavitation include limiting the interval of operation in the part load region but this is not always practical. It has also been proposed to utilize more wear-resistant material for those parts which are likely to be exposed to the effects of cavitation or to use wear-resistant inserts. These techniques, however, are not wholly effective and complicate the design of the pump.

The use of an inducer in conjunction with, for example, a centrifugal pump, has been found to be the most effective way of permitting the pump to operate over a wider range of flow rates than would otherwise be possible. There still exists, however, a need for further improvements to permit large pumps to operate over even wider ranges of flow rates without cavitation damage. This is particularly true, for example, for pumps used in a nuclear reactor powered electric utility where the flow rate through the pump must be varied widely to conform to electrical demands and further where the pump must be designed to operate for up to 20 years.

### Objects of the Invention

It is an object of the invention to provide an improved inducer which will operate over a wide flow range and minimize or eliminate any cavitation damage which would otherwise result from liquid flowing therethrough.

It is another object of the invention to provide such an improvement in a shrouded inducer.

Yet another object of the present invention is to provide a shrouded inducer which will operate over a wide range of flow rates and maintain a high efficiency.

Still another object of the invention is to provide such a shrouded inducer which is readily fabricable without undue cost.

### Summary of the Invention

The foregoing and other objects are achieved by the present invention as defined in claim 1. It provides an inducer which minimizes or substantially eliminates any damage from cavitation while pumping a liquid capable of becoming a two-phase fluid and which is required to operate over a wide range of flow rates.

In detail the inducer of the present invention comprises a, hub rotatably mounted within a pump housing, a plurality of substantially helical blades extending radially outward from the hub and a wall member extending about and encompassing an outer periphery of the substantially helical blades. The wall member, of course, could be an inner surface of the pump housing or in accordance with the preferred embodiment would comprise a shroud extending about the outer periphery and affixed to ends of the substantially helical blades. The essence of the present invention is that adjacent pairs of blades, the wall member and hub form a substantially rectangular cross-sectional flow area, the cross-sectional flow area decreasing from the inlet (suction) end of the inducer to a discharge (pressure) end. Generally, the cross-sectional flow area decreases substantially linearly. In accordance with a particularly preferred embodiment there are provided four substantially helical blades spaced equidistant about the hub and each of the blades extends approximately 180° about an outer periphery of the hub.

### Brief Description of the Drawings

Fig. 1 is a schematic cross-sectional side view of a centrifugal pump having a shrouded inducer;

Fig. 2 is an end view of the inducer taken along plane 2-2;

Fig. 3 is an unfolded view of the inducer;

Fig. 4 is a sectional view taken along plane 4-4 of Fig. 3;

Figs. 5 and 6 are section views of the inducer taken along planes 5 & 6 - 5 & 6 of Fig. 2 showing a cross-section of an inducer constructed in accordance with the prior art and the present invention respectively; and

Figs. 7 and 8 are views taken along plane 7 & 8

- 7 & 8 of Fig. 3 at lines A, B and C showing the fluid flow path through an inducer constructed in accordance with the prior art and the present invention respectively. Figures 1, 2, 5 and 7 are identified as prior art.

## Description of a Preferred Embodiment

Throughout the following description, the same elements or parts of the drawings are designated by the same reference characters. Referring to Fig. 1 therein is depicted a typical shrouded inducer-centrifugal pump assembly 10 which includes a housing 12, a drive shaft 14 extends into housing 12 and is rotatably supported by bearings not shown. A centrifugal impeller 16 located within housing 12 is affixed to drive shaft 14 for receiving rotational forces therefrom and imparting rise in pressure to any fluid passing through housing 12. A shrouded inducer 18 is affixed to a hub end 20 of shaft 14 for increasing the pressure of incoming fluid before it enters impeller 16. Alternatively of course shrouded inducer 18 could be attached directly to impeller 16. Inducer 18 comprises at least one and preferably a plurality of inducer blades 22 which extend radially outward and terminate in a substantially cylindrical shroud member 24. As depicted shrouded inducer assembly 18 is located within a cavity 28 defined by an inner surface 30 of housing 12, which inner surface would form an outer wall extending about an outer periphery of inducer blades 22 if an unshrouded inducer were utilized.

Referring now to Fig. 2, therein is depicted an end view of a preferred form of inducer for the practice of the present invention. Specifically, one having four equally spaced, substantially helical blades which extend approximately 180° about an outer periphery of hub end 20. As depicted, straight radial uncanted blades are shown for simplicity. The leading edge shape of the blades and the front view of the inducer would be equally applicable to a prior art inducer as well as that of the present invention, as is also the case with the unwrapped top view shown in Figure 3. Therein, again in the interest of simplicity, the inducer blades are shown for a simple, straight, constant blade angle. The inducer of the present invention differs from the prior art designs in the shape of the flow passages and the hub contour which is more readily seen in the following figures.

Referring now to Fig. 4, therein is depicted a cross-section of fluid passageway of an inducer constructed in accordance with the present invention. It will be seen that the height of the blade and passage diminishes in a substantially linear fashion in the direction of flow. Further, this same profile would apply for any location of the cross-section within the passageway between the blade pressure side of one blade and an adjacent suction side of another blade. It is a key aspect of the present invention that the blade height reduction along the flow length is basically linear with smooth transitions near the passage entrance and exit at a selected hub diameter. The distinction between the prior art and the current invention is best seen and illustrated in Figs. 5 and 7 (prior art) and Figs. 6 and 8 (current invention).

It will be noted that the prior art inducer utilized an axisymetric hub as shown in Fig. 5. This resulted in a fluid passageway cross-section which is irregular with a sharply reduced passage width between the blade pressure side (P) and the hub, and a suction side passage height shorter than the pressure side, as shown in Fig. 7.

In contrast, the inducer of the present invention utilizes a somewhat irregular or "ratchet shaped" hub. This hub shape will, of course, result in some higher stress levels compared to the axisymetric hub of the comparable prior art inducer. This disadvantage, however, is offset by the advantages gained by the uniform fluid passageway. Referring to Fig. 8, it is seen that the passageway of an inducer constructed in accordance with the present invention is a regular, rectangular shape with suction and pressure sides of the blades of equal height. Thus, fluid passing therethrough travels in a substantially axial direction with minimal cross-currents (secondary flow) such as would be experienced with the prior art inducers. It is this uniformly diminishing cross-sectional flow area as indicated by Fig. 4 that permits the inducer of the present invention to operate over a wider range of flow rates without cavitation than would otherwise be possible.

The increase in inducer efficiency and suction performance of the present inducer is best understood with reference to a simple efficiency calculation. More particularly, wherein secondary flow is defined as the difference between the actual flow and an idealized axisymetrical flow, supporting calculations which qualitatively evaluate the advantage the present invention can be expressed by the following empirical relationship:

$$C = [.1178 \bullet E^2]/[A.R.(1-.2/A.R.)^3] \qquad (1)$$

where

E = turning angle of the cascade

A.R. = passage aspect ratio (passage height/blade spacing)

From Eq. 1 it can be shown that the energy loss coefficient C. is roughly inversely proportional to the passage aspect ratio i.e.:

$$C \sim 1/A.R. = \text{blade spacing/passage height} \qquad (2)$$

The highest losses are associated with the boundary layer separation on the blade suction side. Applying Eq. 1 locally in the suction side region the advantage of the present inducer becomes apparent. Compared to the conventional inducer the passage height along the suction side of the blade (S, Figs. 7 and 8) is greater at the same blade spacing, resulting in reduction of the associated energy loss coefficient C in this critical region (Eq. 2). Since the losses are dominated by the effects along the suction side, the result will be the reduction of the overall secondary flow loss and increase of the inducer efficiency for the inducer of the present invention.

For given head and flow requirements a pump of highest possible specific speed would be smallest, lightest and most economical. Suction performance is most often the limiting factor in this respect. An object of the present invention is to improve suction performance. Improved suction performance can, in general, be obtained by keeping the static pressure in the inducer inlet region high through opening up the fluid passage area (Section Line A between blades $22_B$ and $22_C$, Figure 7 vs blades $22'_B$ and $22'_C$ in Figure 8).

The rectangular throat shape, compared to the conventional passage, has a larger area in the blade suction side region - where the cavitation susceptible, low pressure, high velocity flow normally occurs. This local increase in the flow passage area leads to a local slow down of fluid velocity and a static pressure increase - which in turn leads directly to improved suction performance. The blade height on the pressure side (P) is the same for both channels and is set by the hub inlet and blade tip diameters.

Another advantage of the inducer of the present invention is that it is more readily fabricated at a lesser cost than those of the prior art. Specifically, in the case of fully-machined, integral-shroud inducers, the fluid passage machining is usually performed from both the inlet and discharge ends of the passage. The rectangular shape of the passageway of an inducer in accordance with the present invention allows use of larger cutters, thus significantly reducing machining time and cost. The rectangular shape also simplifies the electrode shape and the forming operations in fabrication, for example, by EDM.

Although the above improvements and descriptions have been related to a shrouded inducer, they are equally applicable to the more conventional unshrouded inducer with regard to the advantages of 2-D passage design.

## Claims

1. An inducer for a pump wherein said inducer and pump are required to pump a liquid capable of becoming a two-phase fluid and operate over a wide range of flow rates, the inducer comprising:
   a hub;
   a plurality of substantially helical blades extending substantially radially outward from said hub;
   a wall member extending about and encompassing an outer periphery of said helical blades, characterized in that
   adjacent pairs of blades, said wall member and said hub forming a substantially rectangular cross-sectional flow area, said cross-sectional flow area decreasing from an inlet end of said inducer to a discharge end of said inducer.

2. The inducer of claim 1 wherein the wall member is a substantially cylindrical shroud affixed to said blades.

3. The inducer of Claim 1 wherein said cross-sectional flow area decreases linearly.

4. The inducer of Claim 1 wherein there are 4 substantially helical blades spaced equidistant about said hub.

5. The inducer of Claim 1 wherein each of said blades extends approximately 180° about an outer periphery of said hub.

6. The inducer of Claim 1 wherein said liquid is an alkali metal.

7. The inducer of Claim 2 wherein there are 4 substantially helical blades spaced equidistant about said hub.

8. The inducer of Claim 6 wherein each of said blades extends approximately 180° about an outer periphery of said hub.

9. The inducer of Claim 7 wherein said liquid is an alkali metal.

## Revendications

1. Roue d'aspiration pour une pompe dans laquelle ladite roue d'aspiration et la pompe doivent être à même de pomper un liquide capable de se transformer en un fluide à deux phases et de fonctionner sur une grande plage de débits, la roue d'aspiration comprenant:
   un moyeu;
   une multiplicité d'ailettes sensiblement hé-

licoïdales, s'étendant sensiblement radialement vers l'extérieur à partir dudit moyeu;

un élément formant paroi s'étendant autour d'une périphérie externe desdites ailettes hélicoïdales en la circonscrivant, caractérisée en ce que:

des paires adjacentes d'ailettes, ledit élément formant paroi et ledit moyeu forment une zone d'écoulement de section transversale sensiblement rectangulaire, ladite zone d'écoulement en section transversale allant en diminuant depuis une extrémité d'admission de ladite roue d'aspiration vers une extrémité d'évacuation de ladite roue d'aspiration.

2. Roue d'aspiration selon la revendication 1, dans laquelle l'élément formant paroi est une enveloppe sensiblement cylindrique fixée auxdites ailettes.

3. Roue d'aspiration selon la revendication 1, dans laquelle ladite zone d'écoulement en section transversale décroît linéairement.

4. Roue d'aspiration selon la revendication 1, dans laquelle il y a 4 ailettes sensiblement hélicoïdales espacées de façon équidistante autour dudit moyeu.

5. Roue d'aspiration selon la revendication 1, dans laquelle chacune desdites ailettes s'étend sur environ 180° autour d'une périphérie externe dudit moyeu.

6. Roue d'aspiration selon la revendication 1, dans laquelle ledit liquide est un métal alcalin.

7. Roue d'aspiration selon la revendication 2, dans laquelle il y a 4 ailettes sensiblement hélicoïdales espacées de façon équidistante autour dudit moyeu.

8. Roue d'aspiration selon la revendication 6, dans laquelle chacune desdites ailettes s'étend sur environ 180° autour d'une périphérie externe dudit moyeu.

9. Roue d'aspiration selon la revendication 7, dans laquelle ledit liquide est un métal alcalin.

## Patentansprüche

1. Pumpeneinlaufkranz für eine Pumpe, wobei der Pumpeneinlaufkranz und die Pumpe eine Flüssigkeit, die zu einem Zwei-Phasen-Fluid werden kann, pumpen und über einen großen Bereich von Durchflußraten arbeiten können müssen und der Pumpeneinlaufkranz aufweist:

eine Nabe,

mehrere sich im wesentlichen radial auswärts von der Nabe erstreckende, im wesentlichen schraubenförmige Schaufeln,

ein Wandteil, das sich um die äußere Peripherie der schraubenförmigen Schaufeln erstreckt und diese umgreift, **dadurch gekennzeichnet,**

daß benachbarte Schaufelpaare, das Wandteil und die Nabe einen im wesentlichen rechtwinkligen Durchfluß-Querschnittsbereich ausbilden, der sich vom Einlaufende des Pumpeneinlaufkranzes zum Auslaßende des Pumpeneinlaufkranzes verringert.

2. Pumpeneinlaufkranz nach Anspruch 1, **dadurch gekennzeichnet,** daß das Wandteil ein im wesentlichen zylindrisches Schaufelversteifungsband ist, das an den Schaufeln befestigt ist.

3. Pumpeneinlaufkranz nach Anspruch 1, **dadurch gekennzeichnet,** daß sich der Durchfluß-Querschnittsbereich linear verringert.

4. Pumpeneinlaufkranz nach Anspruch 1, **dadurch gekennzeichnet,** daß vier im wesentlichen schraubenförmige Schaufeln vorhanden sind, die mit gleichen Anständen um die Nabe angeordnet sind.

5. Pumpeneinlaufkranz nach Anspruch 1, **dadurch gekennzeichnet,** daß jede Schaufel sich um ungefähr 180° um einen äußeren Umfang der Nabe erstreckt.

6. Pumpeneinlaufkranz nach Anspruch 1, **dadurch gekennzeichnet,** daß die Flüssigkeit ein Alkalimetall ist.

7. Pumpeneinlaufkranz nach Anspruch 2, **dadurch gekennzeichnet,** daß vier im wesentlichen schraubenförmige Schaufeln vorhanden sind, die mit gleichen Abständen um die Nabe angeordnet sind.

8. Pumpeneinlaufkranz nach Anspruch 6, **dadurch gekennzeichnet,** daß jede Schaufel sich um ungefähr 180° um einen äußeren Umfang der Nabe erstreckt.

9. Pumpeneinlaufkranz nach Anspruch 7, **dadurch gekennzeichnet,** daß die Flüssigkeit ein Alkalimetall ist.

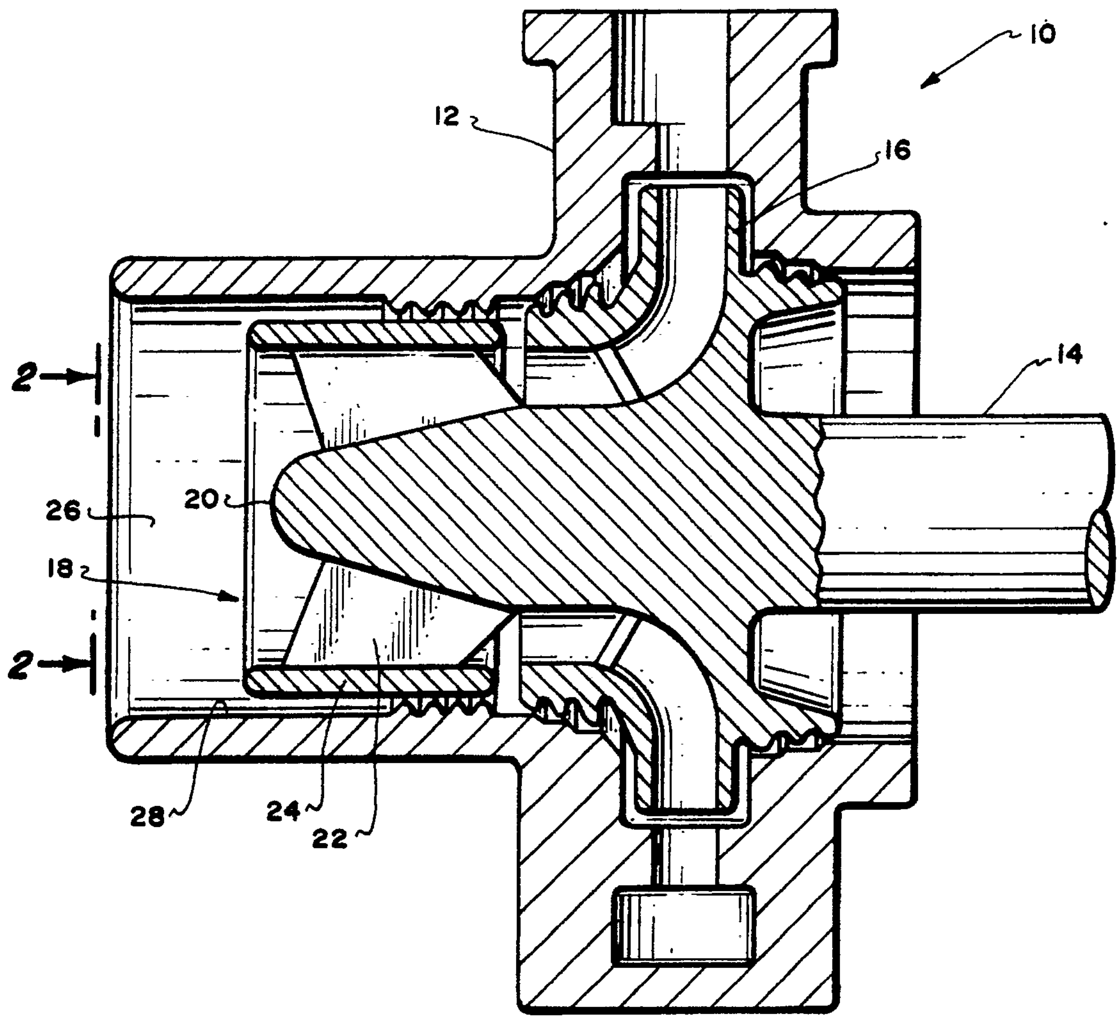


Fig. 1.

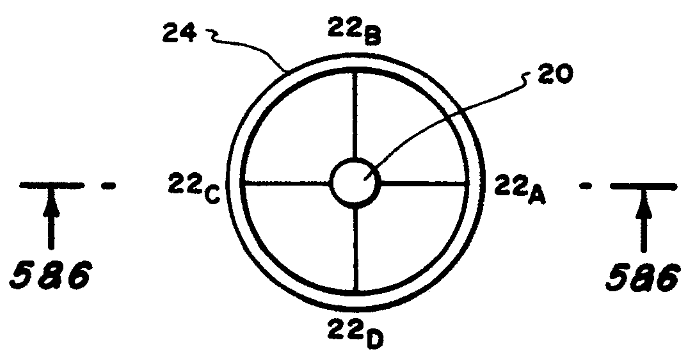


Fig. 2.

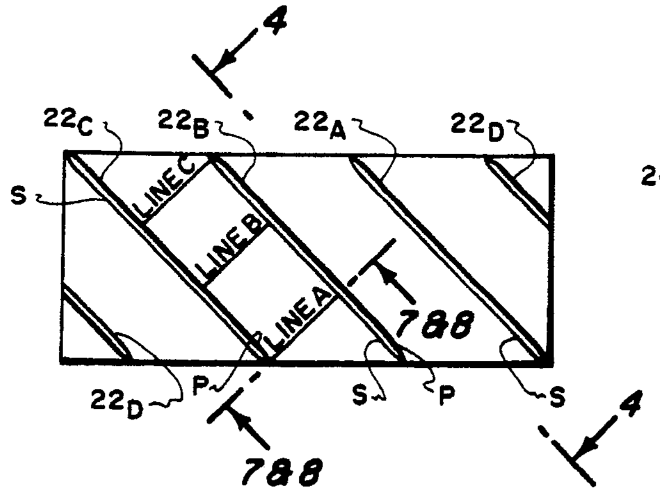


Fig. 3.

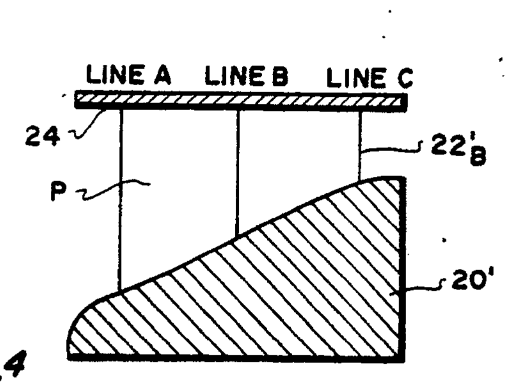


Fig. 4.

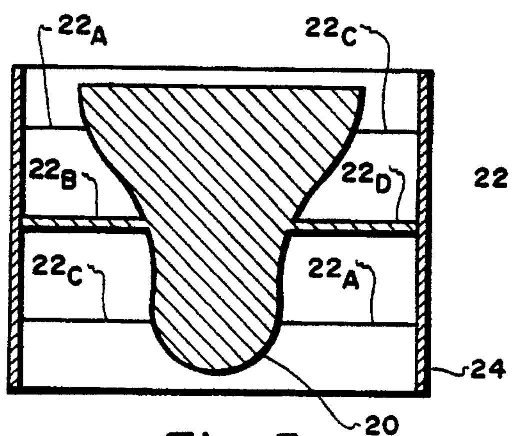


Fig. 5.

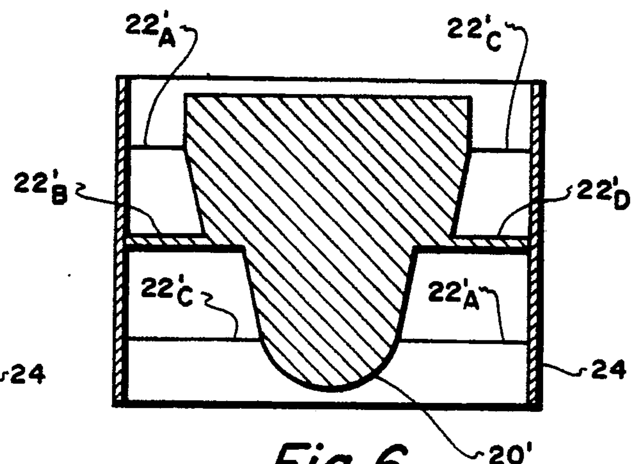


Fig. 6.

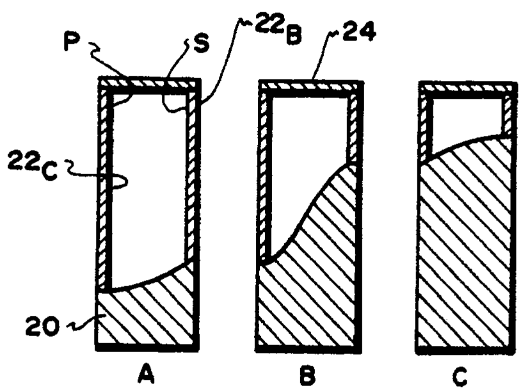


Fig. 7.

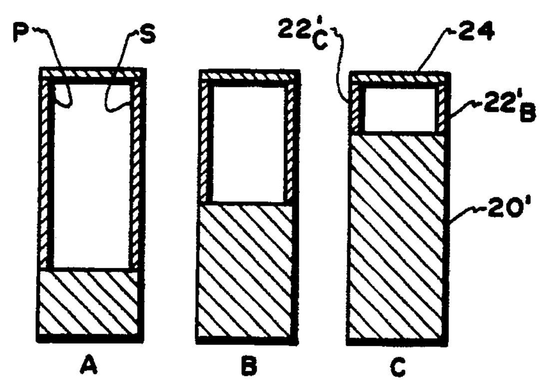


Fig. 8.