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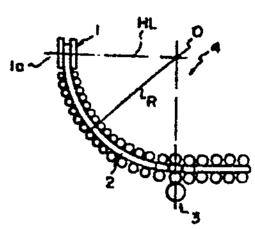
(54) A curved mold for continuous casting.

(57) Conventionally, in a continuous casting machine, in which a curved mold is used, a bent strand is formed and is then straightened at a single straightening point or in a multi-point straightening zone. Since the vertical cooling-water channels are formed in the long-sided mold sections of a conventional curved mold, the distance $\Delta\ell$ between the vertical cooling-water channels and the curved inner surfaces varies in the casting direction, with the result that breakout is likely to occur due to a nonuniform temperature distribution over the curved inner surfaces.

According to the present invention, the longitudinal cooling-water channels (19f, 19ℓ, 26f, and 26ℓ) extend virtually in accordance with the curved inner surfaces (9f, 9ℓ) as seen in the vertical direction of the curved mold, thereby maintaining the temperature of the entire inner surface of the curved mold at 400°C or less and effectively preventing breakout.

Fig. 1



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A CURVED MOLD FOR CONTINUOUS CASTING

The present invention relates to a curved mold for continuous casting which comprises both short-sided mold sections and long-sided mold sections, the inner surface of each of the long-sided mold sections being curved as seen in the vertical direction of the curved mold.

A curved mold for continuous casting which is installed in a known continuous casting machine (CCM) is water cooled, and the curve of each of the long-sided mold sections as seen in the vertical direction of the curved mold has a radius (R) of from approximately 10.5 to 12.5 meters, the center of the radius (R) being on a horizontal line extending across a substantially central portion of the curved mold as seen in a vertical direction. The inner surface of each of the long-sided mold sections is hereinafter referred to as the curved inner surface. Molten steel is supplied into a curved mold and is primary cooled by cooling water which flows through the cooling-water channels of the curved mold. While a strand not yet completely solidifed, and thus having a thin shell is guided until it arrives at a straightening point at the straightening point, the strand, which is bent, is straightened, or unbent, horizontally, and draws a quarter of a circle having a radius defined by each of the radii of the curved inner surface of each of the long-sided mold sections. The strand is then guided in a horizontal direction.

Known curved-type continuous casting machines and a known curved mold for continuous casting are described with reference to Figs. 1 through 4.

In the drawings:

Figures 1 and 2 illustrate known curved-type continuous casting machines;

Fig. 3 is a vertical cross-sectional view of the long--sided mold sections of a known curved mold for continuous casting;

Fig. 4 is a cross-sectional view along line IV-IV of Fig. 3;

Fig. 5 is a graph indicating the relationship between the radius (R) of the curved inner surface of each of the long-sided mold sections and a nonuniform temperature distribution over the curved inner surfaces in the vertical direction of the curved mold, i.e., the maximum temperature difference of the curved inner surface of each of the long--sided mold sections mentioned above as seen in the casting direction;

Figs. 6 and 7 are cross-sectional views of a curved mold for continuous casting according to an embodiment of the present invention; and

Figs. 8 and 9 are drawings similar to Figs. 6 and 7 regarding other embodiments.

In Fig. 1, a curved mold for continuous casting 1, hereinafter simply referred to as the curved mold 1, comprises the long-sided mold sections 1a. Each of the long--sided mold sections 1a has a curved inner surface with a radius (R) of from approximately 10.5 to 12 meters. A horizontal line extending across a substantially central portion of the curved mold 1 as seen in the vertical direction is denoted by HL. The center (O) of the radius (R) of each curved inner surface is on the horizontal line HL. Strand 2 is guided along a quarter of the circle of the strand's path and is subsequently straightened or is horizontally unbent at the straightening point 3. Since there is only one straightening point 3 in known curved--type continuous casting machine 4 illustrated in Fig. 1, the machine height is very high. Curved type-continuous casting machine 4, hereinafter referred to as a high-head CCM, is conventionally used for the continuous casting of slabs.

Recently, attempts have been made to decrease the machine height of a high-head CCM 4 and thus decrease the construction costs. Such attempts are disclosed in Japanese Laid-open Patent Application Nos. 56-14062, 56-14063, 56-14064, and 56-14065 (1981). More specifically, in these attempts, low-head CCM 17 illustrated in Fig. 2 comprises multi-point straightening zone 15, which consists of five pairs of straightening rolls P_1, P_2, P_3, P_4, and P_5 defining radii R_1, R_2, R_3, R_4 and R_5, respectively. The basic radius (R_1) of the curve is 5.8 meters and the machine height (H) which is slightly less than 6 meters. The basic radius (R_1) of the curve of strand's path is defined by the long-sided mold sections 16a. Namely, the curved inner surface of each of the long-sided mold sections 16a defines a small basic radius of the curve of the strand's path, e.g., 5.8 meters, the center (O) of the curve being on horizontal line HL which extends across a substantially central portion of the long-sided mold sections 16a as seen in the vertical direction of the curved mold.

In Figs. 3 and 4, the long-sided mold sections 1a of curved mold 1 (Fig. 1) installed in high-head CCM 4 (Fig. 1) are shown, but the short-sided mold sections of a curved mold 1 are not shown. The long-sided mold sections at the fixed side and the loose side of the strand are denoted by 5f and 5ℓ, respectively. The fixed side and the loose side correspond to the outer side and the inner side of the curve of the curved mold 1, respectively. The long-sided mold sections 5f and 5ℓ comprise copper plates 7f and 7ℓ having curved inner surfaces 9ℓ and 9f, respectively. Cooling water boxes 6ℓ and 6f, which consist of upper and lower cooling chambers, are attached to the outer surface of the copper plate 7f and copper plate 7ℓ, respectively, by means of the bolts 8 (Fig. 4) or the like. The curved inner surface of the long-sided mold section 5f and the curved inner surface of long-sided mold section 5ℓ are defined by the curved inner surface 9ℓ and curved inner surface 9f of copper plates 7f and 7ℓ, respectively. The curve of the curved front surface 9f and the curved inner surface of 9ℓ have radius R_f and radius R_ℓ, respectively, while the curve of curved inner surface 9f at the fixed side of the strand has radius R_f. The center of each of these curves is on a horizontal line (not shown) which extends across a substantially central portion curved mold 1 as seen in the vertical direction. Radius $R\ell$ is from approximately 10.5 to 12 meters.

For the sake of simplicity, the descriptions hereinunder relate only to the long-sided mold section 5f at the fixed side of the strand otherwise specified. However, they also correspond to the long-sided mold section 5ℓ at the loose side of the strand.

Vertical cooling-water channel 10f is formed in copper plate 7f while lateral cooling-water channels 11f, which connect the vertical cooling-water channels 10f with the cooling water box 6f, are formed in the upper and lower parts of the copper plate 7f. A vapor-withdrawing aperture 12f extends between the top surface of copper plate 7f and the lateral cooling-water channels 11f. Although not shown in Fig. 3, a number of vertical and lateral cooling-water channels 10f and 11f and vapor-withdrawing apertures are formed in each long-sided mold section and are arranged in the long width direction of the strand.

In the curved mold 1 of high-head CCM 4 (Fig. 1), the vertical and lateral cooling-water channels 10f and 11f, respectively, are defined by a first copper plate section 14f and a second copper plate section 13f, second copper plate section 13f being grooved and having a recess in which the first copper plate section 14f is capable of being embedded. When forming the vertical and lateral cooling-water channels 10f and 11f, first copper plate section 14f is inserted into the recess of the second copper plate section 13f and then the first copper plate section 14f is engaged with the grooved surface of the second copper plate section 13f.

In a high-head CCM 4 (Fig. 1) provided with a curved mold 1 shown in Figs. 3 and 4, breakout intermittently takes place during the continuous casting of a strand; that is the strand's shell, formed in curved mold 1, breaks and molten steel flows out of the strand, damaging the high--head CCM 4 and decreasing productivity.

When high-speed continuous casting (high-speed withdrawal of the strand) is carried out in low-head CCM 17 (Fig. 2) at a casting speed of 1 meter/min or higher, breakout is more liable to occur than in a high-head CCM 4 (Fig. 1).

It is an object of the present invention to provide a water-cooling structure for the long-sided mold sections of a curved mold so as to suppress breakout and realize high--speed continuous casting, especially in a low-head CCM.

The present inventors studied the phenomenon of breakout, which especially occurs in high-speed continuous casting at a casting speed of 1 meter/min or higher. As a result, the present inventors recognized that half or more than half of the incidents of breakout in high-speed continuous casting occurs due to the strand's shell sticking to the inner surface of curved mold 1 or 16. Also, the present inventors discovered that in order to prevent the strand's shell from sticking to the inner surface of the curved mold 1 or 16, curved mold 1 or 16 should be designed in such a manner that the temperature of the entire inner surface of curved mold 1 or 16 is maintained at 400°C or less.

A curved mold for continuous casting comprising short--sided mold sections and long-sided mold sections each having a curved inner surface as seen in the vertical direction thereof according to the present invention is characterized in that logitudinal cooling-water channels of the long-sided mold sections extend in a direction virtually in accordance with the curve of the inner surface of each of the long-sided mold-sections as seen in the vertical direction thereof.

The studies of the present inventors, which were conducted before completing the curved mold according to the present invention, are now described.

The present inventors examined the cooling construction of the copper plate for a curved mold 1 (Figs. 1 and 3), which is employed in a high-head CCM 4 (Fig. 1), and concluded the following:

1. The curved inner surface of the long-sided mold section 5f, namely curved inner surface 9f of curved mold 1, is a concavely curved surface having the radius R_f while the curved inner surface of long-sided mold section 5ℓ, namely curved inner surface 9ℓ of the curved mold 1, is a convexly curved surface having the radius $R_ℓ$. Since the vertical cooling-water channels 10f and 10ℓ extend through the long-sided mold sections 5f and 5ℓ, respectively, in the vertical direction of curved mold 1 distance $Δℓ$ (hereinafter simply referred to as distance $Δℓ$), between the vertical water-cooling channels 10f and 10ℓ and the curved inner surfaces 9f and 9ℓ, respectively, varies in the vertical direction of the curved mold 1. For example, in a conventional curved mold, in which the radius R_f of the curved inner surface 9f is specifically 10.5 meters, the height of the curved mold is 700 mm, and the center of the curve having radius R_f is on a horizontal line extending across a portion of the curved mold 350 mm below the top of the curved mold, minimum distance $Δℓ$ being determined as being 30 mm in the light of the life of the curved mold. In this case, the maximum value of distance $Δℓ$ amounts to 36 mm, with the result that distance $Δℓ$ varies by 6 mm. In other words, the thickness of the second copper plate section 13f varies by 6 mm in the vertical direction of the curved mold. In a case where the difference between the maximum and minimum values of distance $Δℓ$ ($Δℓ_{max} - Δℓ_{min}$) in the vertical direction of the curved mold is 6 mm, such difference $Δℓ_{max} - Δℓ_{min}$ results in the overall thermal conductivity of primary cooling varying in the casting direction. More specifically, primary cooling, which is determined according to the thermal conductivity of the strand's shell, the second copper plate section 13f, and the vertical cooling-water channel 10f, varies in the vertical direction of the curved

mold, and the difference in the overall thermal conductivity corresponds to from 1% to 5%, with the result that the temperature of the curved inner surface 9f varies by 25°C at the maximum as seen in the vertical direction of the curved mold. In other words, the temperature distribution of the curved inner surface 9f is nonuniform in the casting direction.

2. In a conventional curved mold having radius R_f , distance $\Delta\ell$, and the height specified in item 1 above, the temperature of the curved inner surface 9f varies during continuous casting but difference $\Delta\ell_{max} - \Delta\ell_{min}$ mentioned above is maintained. In the case of high-speed continuous casting, said temperature varies between 350°C and 420°C specifically at a portion of long--sided mold section 5ℓ where difference $\Delta\ell$ is maximal. Incidentally, the heat resistance of the vertical cooling--water channel 10f is approximately 5% of the overall heat resistance of the strand's shell, copper plate section, and vertical cooling-water channel 10f, with the result that even by enhancing the cooling water flow rate in the vertical cooling-water channel 10f, the temperature of the curved inner surface 9f cannot be lowered. When this temperature exceeds 400°C, breakout may occur.

The present inventors further considered the case of low-head CCM 17 in regard to how the radius of the curved inner surface of the mold exerts an influence on the non-uniform temperature distribution curved inner surface 9f. The present applicant has already proposed a low-head CCM such as that shown in Fig. 2 so as to obtain strands having a high temperature and being free of defects. In accordance with a decrease in machine height, the radius of the curved inner surface of the curved mold inevitably decreased, with the result that the nonuniform temperature distribution of the curved inner surface becomes more serious. More specifically, as shown in Fig. 5, which indicates the relationship between the basic radius (R) of the strand's path and the nonuniform temperature distribution in the vertical direction of the curved mold in centigrade (that is, the maximum temperature difference of the curved inner surface as seen in the casting direction, hereinafter simply referred to as the maximum temperature difference), such nonuniform temperature or the maximum temperature difference is increased in accordance with the basic radius (R) of the curve of the strand's path. Especially, when the basic radius (R) of the curve of the strand's path is 6 meters or less, said nonuniform temperature distribution or the maximum temperature difference amounts to 40°C or more.

The present inventors further examined whether a decrease in the thickness of copper plate 7f, that is, a decrease in the heat resistance of the copper plate 7f, would make it possible to decrease the temperature of a portion of the curved inner surface 9f where the thickness of copper plate 7f is the greatest to a value of 400°C or less and thus effectively prevent breakout. In such a case, minimum distance $\Delta\ell_{min}$ becomes 30 mm or less, thereby creating problem in the light of the life of curved mold 1. When the life of a curved mold is short in continuous casting, productivity is decreased and the cost of producing strands is increased.

After considering the above-mentioned points, the present invention was completed. According to the present invention, vertical cooling-water channels in the long--sided mold sections extend in a longitudinal direction virtually in accordance with the curve of the inner surface of each of the long-sided mold sections as seen in the vertical direction of the curved mold, thereby maintaining the temperature of the entire inner surface of the curved mold at 400°C or less and effectively preventing breakout due to the strand's shell sticking to the inner surface of the curved mold, while at the same time not decreasing the life of the curved mold. Therefore, according to the curved mold of the present invention, high-speed continuous casting at a casting speed of especially from 1.4 to

2.0 meters/min is possible while effectively preventing breakout and prolonging the life of the curved mold so that it is equivalent to or longer than that of a conventional curved mold.

In Fig. 6, an embodiment of the curved mold according to the present invention is illustrated. In the figure, the curved mold is denoted by 18, and the vertical cross-sectional structure of the long-sided mold sections 5ℓ and 5f having the curved inner surfaces 9ℓ and 9f, respectively, is shown but the known vertical cross-sectional structure of the short-sided mold sections is not shown. Curved cooling-water channels 19f and 19ℓ are formed in the long-sided mold sections 5f and 5ℓ, respectively, in such a manner that they are delineated by a single curve. More specifically, in the curved cooling-water channel 19f, which is formed in the long-sided mold section 5f, the radius of the curve is $R_f + \Delta\ell$ while in the curved cooling-water channel 19ℓ, which is formed in the long-sided mold section 5ℓ, the radius of the curve is $R_\ell + \Delta\ell$. Distance $\Delta\ell$, which indicates the distance between the cooling-water channels 19f and 19ℓ and the curved inner surfaces 9f, 9ℓ, respectively, and is adjusted to 30 mm when the radius R_f of curved inner surface 9f is 10.5 meters. Since distance $\Delta\ell$ is constant in the casting direction, an advantage results in that the nonuniform temperature distribution on the curved inner surface 9f as seen in the curved direction of curved mold 18 is eliminated, especially in the upper portion of the curved mold 18 where the temperature is high. In curved mold 18 according to the present invention, in which distance $\Delta\ell$ is adjusted to 30 mm and radius R_f of curved inner surface 9f, specifically, is 10.5 meters, the thickness of the second copper plate section 13f is less than that of a conventional curved mold 1 (Fig. 3) when the thickness of conventional curved mold 1 (Fig. 3) is measured at the upper and lower portions thereof and between the curved inner surface 9f and the cooling-water channels, i.e., vertical cooling-

-water channel 10f (Fig. 3) and the curved cooling-water channel 19 (Fig. 6). That is, no locally thick portion of the second copper plate section 13f where $\Delta\ell_{max} - \Delta\ell_{min}$ = 6 mm is present in curved mold 18 (Fig. 6) of the present invention. As a result, not only it is possible to maintain the entire inner surface of the curved mold 18 at a temperature of 400°C or less and thus effectively prevent breakout due to the strand's shell sticking to the inner surface of curved mold 18 but it is also possible that the life of the curved mold 18 may not be shortened to less than that of a conventional curved mold 1 (Fig. 3) since the thickness of the second copper plate section 13f measured between curved cooling-water channel 19f and the curved inner surface 9f is the same as the minimum thickness, i.e. 30 mm, of the second copper plate section in conventional curved mold 1 (Fig. 1).

In the curved mold 18 (Fig. 6), the curved cooling-water channel 19f is defined and formed in a manner similar to that of vertical cooling-water channel 10f (Fig. 3), that is, by means of the first copper plate section 14f and the second copper plate section 13f, which is grooved.

In low-head CCM 17 (Fig. 2), in which the radius R_f is less than 10.5 meters (R_f < 10.5 m), the distance $\Delta\ell$ of a curved mold 18, which has a small radius, is preferably a value high enough to ensure that the temperature of the entire inner surface of a curved mold 16 is maintained at 400°C or less in the light of the life of the curved mold 18.

In Fig. 7, the structure of the long-sided mold section 20ℓ according to an embodiment of the present invention is shown, and a long-sided mold section having the same structure can be used at the fixed side of the strand (not shown). In this embodiment, the curved cooling-water channel 19ℓ can be easily fabricated. The long-sided mold section 20ℓ comprises: a curved copper plate section 21ℓ having a curved groove on one surface thereof; and a cooling-water box 22ℓ comprising a curved copper plate section 22aℓ, which is provided with a cooling water inlet and outlet. The curved copper plate section 21ℓ is secured to the curved copper plate section 22aℓ so as to form the curved cooling-water channel 19ℓ, which is parallel to the curved inner surface 23ℓ as seen in the vertical direction of the curved mold.

In Figs. 8 and 9, embodiments of the curved mold according to the present invention are illustrated. In these figures, the curved mold is denoted by 24 and 27, respectively, and the vertical cross-sectional structure of the long-sided mold sections 5f and 5ℓ having the curved inner surfaces 9f and 9ℓ, respectively, is shown but the known vertical cross-sectional structure of the short-sided mold sections is not shown.

In Fig. 8, longitudinal cooling-water channels 26f and 26ℓ of the long-side mold sections 5f and 5ℓ, respectively, are defined by three communicating linear cooling-water channels $25f_{(1)}$, $25f_{(2)}$, and $25f_{(3)}$ and three communicating linear cooling-water channels $25\ell_{(1)}$, $25\ell_{(2)}$, and $25\ell_{(3)}$, respectively, and extend virtually in accordance with the curve of the curved inner surfaces 9f and 9ℓ as seen in the vertical direction of the mold. Not only three but two or more than three communicating linear cooling-water channels may define longitudinal cooling--water channels 26f and 2ℓ.

In Fig. 9, longitudinal cooling-water channels 26f and 26ℓ of the long-sided mold sections 5f and 5ℓ are separated into upper, middle, and lower channels $25f_{(1)}$, $25f_{(2)}$, $25f_{(3)}$ and $25\ell_{(1)}$, $25\ell_{(2)}$, $25f_{(3)}$, respectively. So that cooling water can be separately supplied into and separately withdrawn from the upper, middle, and lower channels $25f_{(1)}$, $25f_{(2)}$, and $25f_{(3)}$ in the case of the long-sided mold section 5f, the cooling--water box 6 is separated into the upper, middle, and lower sections $6f_{(1)}$, $6f_{(2)}$, and $6f_{(3)}$, these sections being provided with separate lateral cooling-water channels

$11f_{(1)}$, $11f_{(2)}$, and $11f_{(3)}$, respectively. Not only three but also two or more than three separated longitudinal channels may be used so as to define, by the arrangement of these separated channels, a cooling-water channel which extends virtually in accordance with the curve of curved inner surface 9f as seen in the vertical direction of curved mold 27.

CLAIMS

1. A curved mold for continuous casting comprising short-sided mold sections and long-sided mold sections each having a curved inner surface which is curved as seen in the vertical direction of the mold, characterized in that

the longitudinal cooling-water channels (19f, 19ℓ, 26f, and 26ℓ), extend virtually in accordance with the curve of the curved inner surface (9f, 9ℓ) of each of the long-side mold sections (5f, 5ℓ) as seen in the vertical direction of the curved mold.

2. A curved mold for continuous casting according to claim 1, characterized in that

said longitudinal cooling-water channels (19f and 19ℓ) are delineated by a single curve.

3. A curved mold for continuous casting according to claim 1, characterized in that

each of said vertical cooling-water channels (26f and 26ℓ) is defined a plurality of communicating linear cooling-water channels ($25f_{(1)}$, $25f_{(2)}$, $25f_{(3)}$, $25ℓ_{(1)}$, $25ℓ_{(2)}$, and $25ℓ_{(3)}$).

4. A curved mold for continuous casting according to claim 1, characterized in that

each of said longitudinal cooling-water channels (26f and 26ℓ), is divided into a plurality of channels ($25f_{(1)}$, $25f_{(2)}$, $25f_{(3)}$, $26f_{(1)}$, $26f_{(2)}$, and $26f_{(3)}$), each of said channels being provided with lateral cooling-water channels ($11f_{(1)}$, $11f_{(2)}$, $11f_{(3)}$, $11ℓ_{(1)}$, $11ℓ_{(2)}$, and $11f_{(3)}$), thereby allowing separate supply of and withdrawal of the cooling water.

Fig. 1

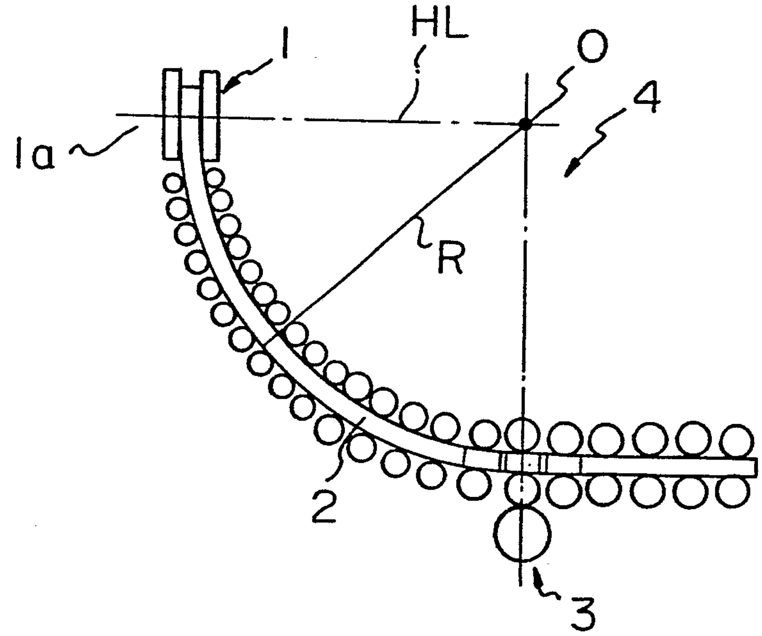


Fig. 2

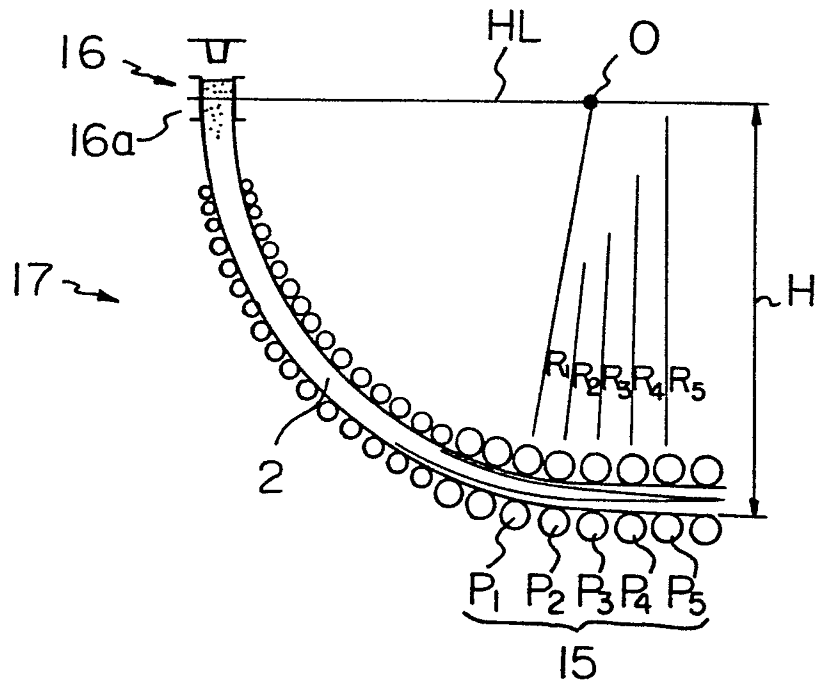


Fig. 3

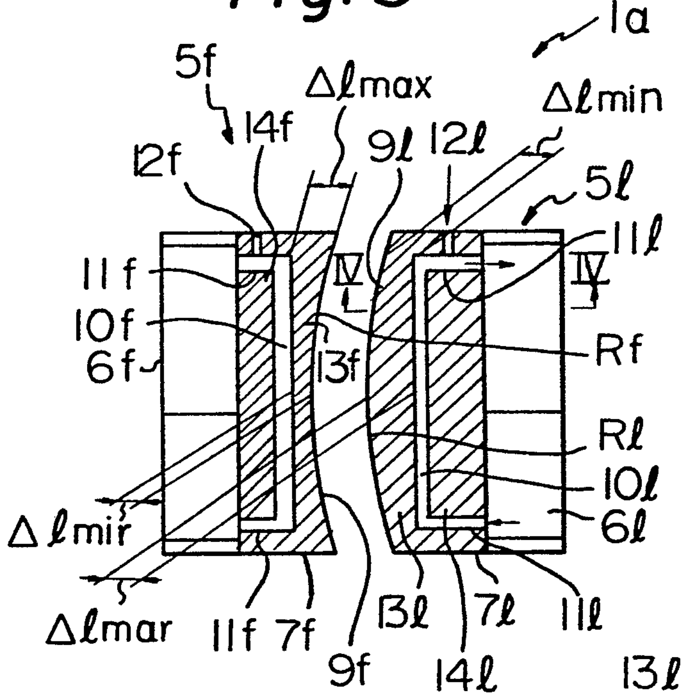


Fig. 4

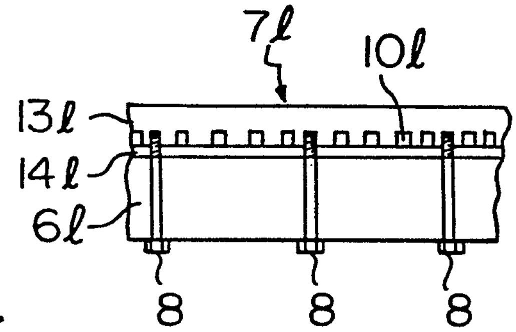


Fig. 5

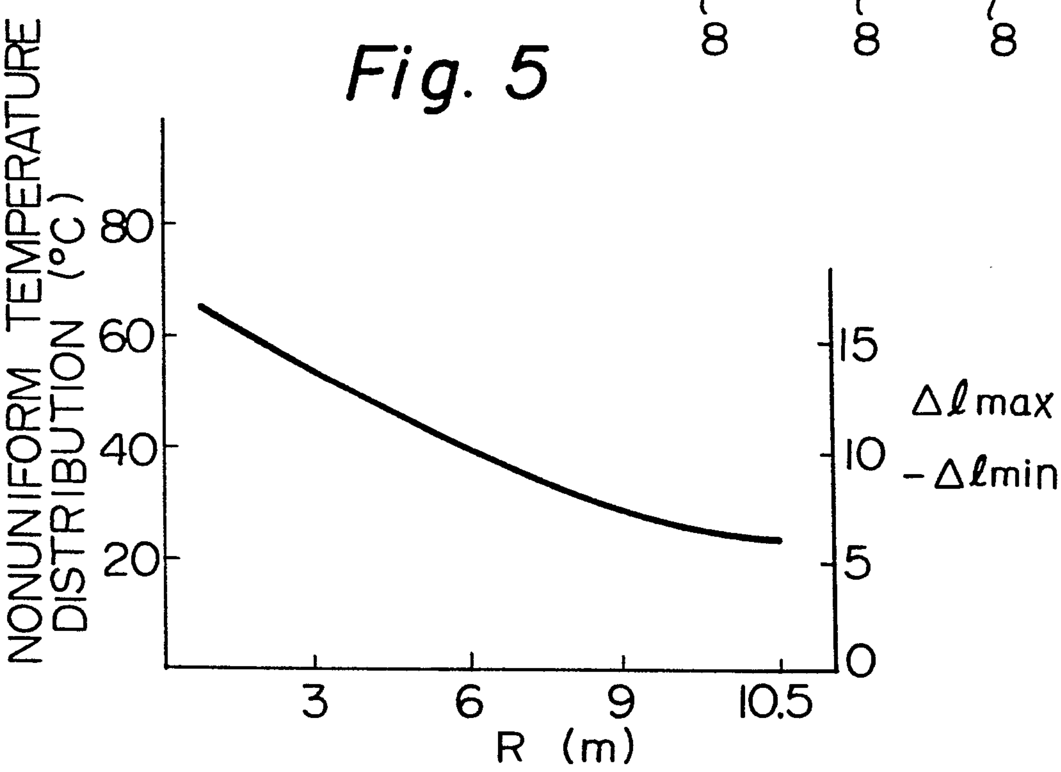
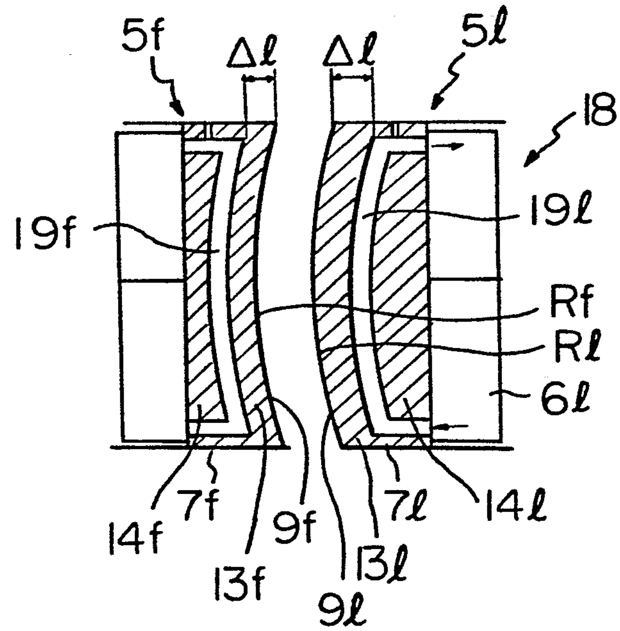


Fig. 6


5f
Δℓ
Δℓ
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18
19f
19ℓ
Rf
Rℓ
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13f
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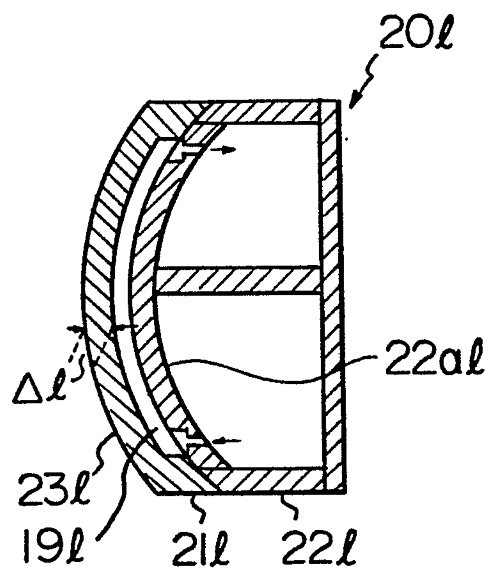
9ℓ

Fig. 7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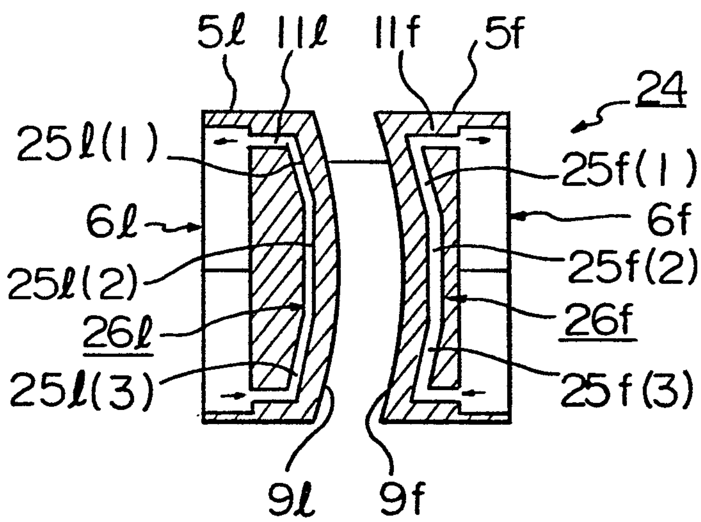
22ℓ

Fig. 8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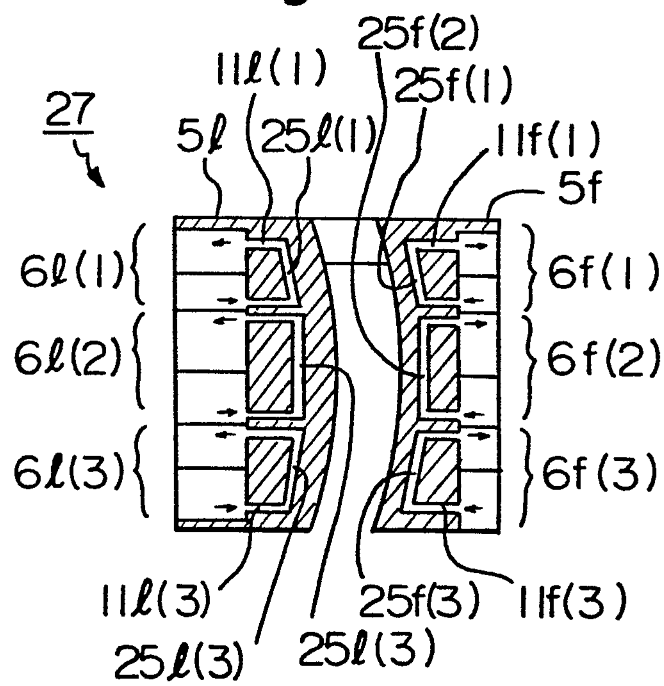
9ℓ
9f

Fig. 9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European Patent Office

EUROPEAN SEARCH REPORT

0071401
Application number

EP 82 30 3840

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	US-A-3 978 910 (GLADWIN) *Column 1, lines 53-64*	1,2	B 22 D 11/04 B 22 D 11/00
X	US-A-3 623 533 (KHOREU) *Figure 1*	1,2	
A	DE-A-1 558 312 (SCHLOEMANN) *Page 2, line 9 - page 3, line 25; page 5, line 1 - page 6, line 7*	3,4	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			B 22 D 11/04 B 22 D 11/00 B 22 D 11/14

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22-10-1982	SCHIMBERG J.F.M.

CATEGORY OF CITED DOCUMENTS

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